THE ENGINEER

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AERONAUTICAL PROSPECTS

Whatever doubts may have existed in past years as to the purpose of the Society of British Aircraft Constructors Flying Display and Exhibition, resulting in suggestions that it should emulate the great international shows and take place less frequently than annually, have now expired. It is clear that " Farnborough " is now neither more nor less than a trade fair, and that its frequency is dictated by the desire of the industry to earn foreign currency. However, because this country is still isolated by restrictions and formalities, if not time and weather, from its neighbours, there are many who visit Farnborough in an attempt to assess the standing of this country in aviation. For them the 1958 show has some significant exhibits ; two to which we attach importance are the " Rotodyne," the first vertical-take-off airliner, and the hull (the profit-earning part) of the new Armstrong-Whitworth freighter/coach transport that is now progressing according to schedule towards its first flight. These aircraft have much in common ; both depend to a minimum upon fundamental aerodynamic advances that require extensive and expensive research and proving, and both will be able to do a job that no other machine can tackle, instead of merely offering a marginal and disputable superiority in narrowly defined operations. The more conventional machine is handicapped by a limited-life wing inherited from military forebears that esteemed the aerodynamic efficiency of an unbroken upper surface more highly than the structural simplicity of an uninterrupted tension skin ; however, its builders trace a distinguished history to the very genesis of mechanical engineering—and that they are still well abreast of contemporary practice was illustrated by their introduction to this country of tank testing of pressurised fuselages—so that structural integrity is unlikely to elude their designers. The " convertiplane " may prove to need much hard and costly development effort before even the most forward-looking of operators will experiment with it, and we should feel more sanguine if such a major undertaking were the sole pre-occupation of its sponsors.

But while there may be reassuring prospects for the industry in the spectrum of civil aircraft, since a constructor may choose to build what he can best sell, the visitor who regards the industry as part of the country's armoury has both less to see and more to fear. It is, of course, no longer envisaged that the most advanced and ambitious weapons systems shall be undertaken in this country, but there is no alternative to manufacturing what cannot be imported. Once the strategic bombardment missile is in being, the first role of an air force in importance is its first role in history—reconnaissance ; there is an urgent requirement for a reconnaissance aircraft with the very impressive radius of action of 1200–1500 miles, much of it in hostile air space. Since no other power is placing reliance on missiles for offence, the only foreign machines with such capability are likely to be basically bombers and correspondingly elaborate and expensive ; it may be possible to adapt a very ambitious fighter such as the " Arrow," but, if not, this fairly straightforward project should be under way already. Even more disturbing are the problems of equipment for the Royal Navy. The enormous " Sea Vixen " soon to be delivered is unquestionably the last variation on a subsonic theme and no amount of optimism, or heroism, will alter its status as an interim model ; a warship with its radar in action is so clearly an ideal target for a " stand-off bomb " that a truly all-weather fighter of contemporary performance, able to prevent an unhurried surveillance of the fleet and analysis of its electromagnetic emissions, is an indispensable condition for carrier operations against any opponent worthy of the name. The need of the Navy for offensive missiles seems also to have been given too little emphasis in view of the fact that it is no longer intended to deploy forces numerically superior to those of any likely enemy ; the ability to fight at extreme range is the obvious solution to the resulting problems. The development of such cheap and troublefree engines as the ramjet should allow the aircraft industry to evolve a vehicle that would scream over the waves at roughly the muzzle velocity of a battleship's heavy shell, but be capable of being launched even from a modified merchant ship. The Army appears now to have its choice of anti-tank missiles, the design of such vehicles having been a very popular exercise with European aircraft constructors, and the fact that its deployment is exceedingly closely circumscribed by its lack of high speed transport—in nuclear campaigns mobility is the condition of survival—is of course attributable to the inadequacies of the Treasury rather than the aircraft industry.

A portent for the probable future can perhaps be found in one of the more unusual exhibits, an aero-engine of United States origin. It is quite possible that this engine will be produced in Great Britain, since at least one of the helicopter airframes in which it has been used is already being built here. Less important items, such as auxiliary gas turbines, alternator drives, landing wheels and brakes, are already frequently imported or licence built, with the results that we share in the lessons of foreign experience and facilitate maintenance without any serious restrictions upon the variety of the machines we undertake. This trend can hardly fail to be accelerated as imported weapons reappear in the armouries of the fighting services, and by the initiation, which is coming to be deemed desirable as well as necessary, of some measure of free trade. Here, perhaps, we see an exciting prospect. It must be acknowledged that the strength of the British industry, in men and facilities, is such that it takes relatively long—too long—to bring an aircraft to the stage of readiness for service. The only counter for this state of affairs is to undertake projects before they are initiated elsewhere, as was done in the case of the " Comet," which first appeared at Farnborough in 1949, but is nevertheless still expected to be introduced on to some civil air routes. Our nearest neighbour in the North Atlantic Treaty Organisation is the accepted

source of the more advanced and ambitious prototypes in the " Old," if not the whole, world ; the daring designers and gifted development engineers of France, despite the vast disruption of the war, have in late years performed inspiring full-scale experiments with tailless deltas, extreme aspect ratios, ramjets, rocket propelled aircraft, machines independent of airfields, and, of course, jet airliners of the pusher configuration. But consistently the most exciting of these projects have suffered the fate of our own irreplaceable and badly missed " V.1000," so that their creators have profited little from their virtuosity. But if British boasts of an ability to make things that do actually reproduce in service the designer's intentions are well founded, this country can offer to France something no less valuable than the Gallic flair for bold pioneering. Combinations such as Blackburn/Turbomeca and Hurel-Dubois/Miles might presage a future in which aeronautical engineering in Europe became self-sustaining.

SCIENCE AND BUSINESS

It is particularly appropriate that Sir Alexander Fleck should be President of the British Association for the Advancement of Science this year. For this year that Association's attempt to get back to its original purpose of interesting laymen in the doings of scientists is really getting under way. Sir Alexander, though unquestionably a scientist, has no specialist scientific interest and, as chairman of Imperial Chemical Industries since 1953, he has great experience of administration. In that latter position he will have been well placed to appreciate how important it is that the layman should understand something about science ; and that the scientist should understand something about business. Indeed, he entitled his address " Science and Business : a Balanced Partnership."

We reprint some of the Address elsewhere in this issue. It is full of good things ; for Sir Alexander has the gift of making challenging statements succinct " In a population which depends so much on science, it is sad to think how few people clearly understand what it is all about " ; and again : " Our capacity to extend science and education largely depends on our ability to run business successfully." We wonder to how many business men the first of those thoughts has occurred and to how many scientists the second. That second remark just possibly might be held untrue of " pure science." But it is certainly true of applied science. Look, for example, at what happened to the synthetic dyestuffs industry in this country when the business side neglected scientific effort and thus lost the lead given it by Perkins. It took a major effort during and after the first world war to get a chemical industry going again and the fact that the major company in that industry has a scientist as its chairman shows how well it has learnt the lesson. But not every one in every industry has learnt it. Sir Alexander quotes the managing director " who went on record last May " as writing : " The place of the expert is not in the saddle but as the assistant and the adviser. . . . The scientist must be on tap, not on top." We suspect also—and deplorably—that many a man in a Ministry would agree with that managing director. Sir Alexander was speaking throughout his Address mainly of men trained as scientists. Yet much that he had to say is equally applicable to engineers. " Science," he remarked, " has more to offer than mere tools. If offers the whole philosophy of the scientific approach to the problems of management " and rubbing the same point home in the opposite way, " It is just as great a mistake to believe that unqualified men who came up what used to be called ' the hard way,' are generally adequate, let alone best, for production work, as to hold that good technical people are wasted in such jobs as plant management." There are still whole industries in this country that have that lesson to learn, judging by the very small proportion of trained technologists or scientists they employ.

Towards the end of his Address, Sir Alexander came to speak of education. Much that he said went straight to our hearts, for we are fond, too, of stressing the same thing : " I have in the past on several occasions declared my belief that the gulf which at present separates our scientists and non-scientists is much more easily bridged than is often imagined . . . the qualities of mind which are fostered by studying chemistry and history are very much alike." It is folly for scientists to assume " arts " men to be incomprehensible and equal folly for arts men to assume science is something too abstruse for any but specialists to understand. Once get a scientist and an " artist " talking naturally together and each proves interesting, provocative and by no means incomprehensible to the other. For both have trained critical and observant minds disciplined in much the same way to seek the truth. Each, if of high degree, has the intellectual qualities of curiosity, judgment and imagination. Nor is it necessarily true to assume that the scientist will be less easily excited emotionally than the other. The gulf to which Sir Alexander referred is, we believe, already closing. Architects are learning how interesting it can be to design industrial buildings. Artists are finding in science subjects for abstract design and in industry fields for more illustrative work. Historians in turning to social history find themselves compelled to take interest in industrial processes. The very fact that Sir Alexander occupies the position he does is evidence that the gulf is closing.

DETECTION OF BOMBS

A conference which continued for some weeks in Geneva has once again demonstrated the fact that the scientists and technologists of the world's nations can get along together much more satisfactorily than statesmen and politicians. Representatives of Britain, the United States, Canada, France, Russia, Czechoslovakia, Poland and Rumania have been examining and discussing whether it would be possible to detect and identify nuclear explosions. They came to the conclusion that it would be technically possible to set up a workable and effective control system for the detection of violations of a possible agreement on the world-wide cessation of nuclear weapon tests. Various methods of detecting nuclear explosions are possible, including the collection of samples of radioactive debris, the recording of seismic, acoustic and hydro-acoustic waves, and the radio signal method. But it was clear to the representatives that there could be events which might or might not be nuclear explosions so that on-site inspection would be necessary for certain unidentified events. This conclusion may open the way to an agreement between the U.S.A., Britain and Russia to suspend for a period and eventually *sine die* any further tests of nuclear weapons. Save for a few scientists and technologists whose life's work it may have become to make " bigger and better " bombs, the whole world would sigh with relief were such an agreement reached. It would do so not only because no one can feel quite sure that no harm is being done to the human race through the raising—however slightly—of the natural radioactivity to which it is exposed each time a nuclear weapon goes off, but also because of a perception that cessation of testing

must sooner or later lead to an end of improvement in bomb building techniques. For even the most dedicated of " boffins " must surely lose heart if he is never allowed to make the final crucial test of the rightness of his work ! But we wonder, ought a ban to be quite so absolute ? The loosing off of nuclear weapons has been done primarily with the object of improving them as weapons. But we have no doubt there has also been an addition to scientific knowledge, too ; knowledge that may prove applicable for useful peaceful purposes. Perhaps an international agreement to cease the testing of nuclear weapons should leave room for the testing of nuclear explosives for scientific purposes.

PRIORITIES AND PLANETS

The recent attempt by the Americans to send up a " lunar probe " to circle the moon has touched off a minor controversy. A number of people are suggesting that man has got his " priorities " muddled and that instead of expending vast sums of money on exploration of the moon he would do far better to use the money for an active attack upon malaria or upon some other scourge on mankind. Some of those who thus object to this American (or Russian) activity are, of course, in reality objecting to scientific and technological advances of any kind. It is a fact which engineers always find a little strange that some people are so conservative or so afraid of unknown possibilities that they would prefer all progress to cease forthwith. There are, indeed, so many of them that they would be a power in the land if only they could decide amongst themselves when it was that progress ought to have ceased, that is when it was that man lived in a Golden Age. Some would have had all progress cease in the times of Ancient Greece or Rome ; others think of the Gothic period in England as the Golden Age ; others place it in the days of the first Elizabeth, of the Restoration or of the Georges. Still more think of the late Victorian or early Edwardian time before Europe fell into a welter of wars. Some—quite incomprehensibly to us—suggest that now is the time to stop though why they should think that as from now on, rather than from any other moment in the past or the future, any change must be for the worse we cannot imagine.

But not all of the objection to lunar probes is that kind of conservatism. Some of those who suggest that our priorities are wrong want research to continue ; but along a different line. They can see that an attack upon, say, malaria could within a reasonable space of years probably bring the scourge to an end. They cannot see how discovering what is on the far side of the moon, or having a closer look at Venus or Mars, is going to benefit mankind. It is, of course, a possibility, quite a high possibility, judging from what astronomers report to us about the nature of the planets of the Solar System, that there will be no direct benefit to mankind. All one can say is that geographical exploration in the past has for the most part benefited mankind and that Europe in particular greatly benefited from the expeditions of Vasco da Gama and Columbus. Moreover, to judge from the difficulty which these men (and many other explorers since) had to raise support for their projects most of their contemporaries rated their " priority " as low ! Yet it must be conceded that conditions anywhere in the Solar System other than upon earth may be incapable of supporting human life. What then ? Is the attempt to explore it still to be justified ? But the value of an exploration cannot be assessed until it has been done and an attempt has been made to exploit its results. How can one claim that man's priorities are out of balance unless one claims also much more complete knowledge than exists at present about what exploration will reveal ?

The direct return upon man's investment in rockets, satellites, lunar-probes and " space-probes " may or may not be immense. We cannot tell. But there is one thing which those who argue about priorities overlook. In making rockets and all the controls and transmission systems that go with them man is working at the limits of his scientific and technical knowledge. Whether or not men ever reach and establish themselves upon the surfaces of the moon and planets, scientists and engineers are acquiring new knowledge which can be and will be ploughed back to leaven all technology. Who can weigh that new knowledge ? Who can weigh it against the knowledge that might be gained from, say, a more concentrated attack on malaria than is being made at present and against the saving of life that might follow ? Even if man fails in the attempt to live elsewhere than on the earth's surface, no one could feel sure that in choosing to attempt to explore the Solar System he had his priorities all wrong. Dare we suggest that part at least of man's successful evolution may be traced to an abiding urge to explore and to find means of adapting himself to new circumstances? There would be something rather shameful were man not to attempt the exploration of the Solar System now that the opportunity is beginning to open before him.

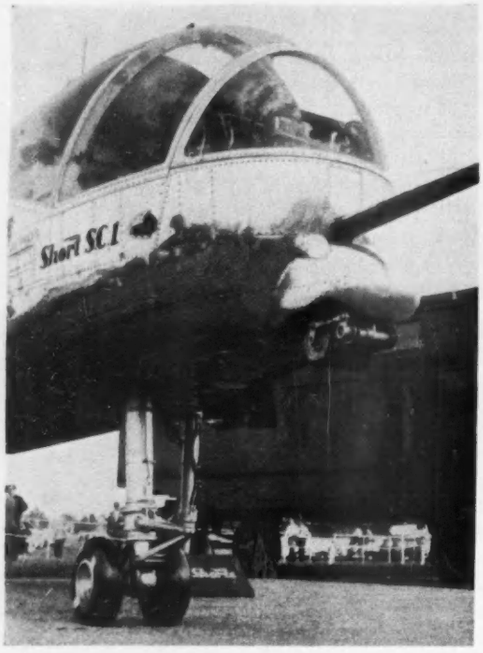
The Engineer— 100 Years Ago (SEPTEMBER 3, 1858)

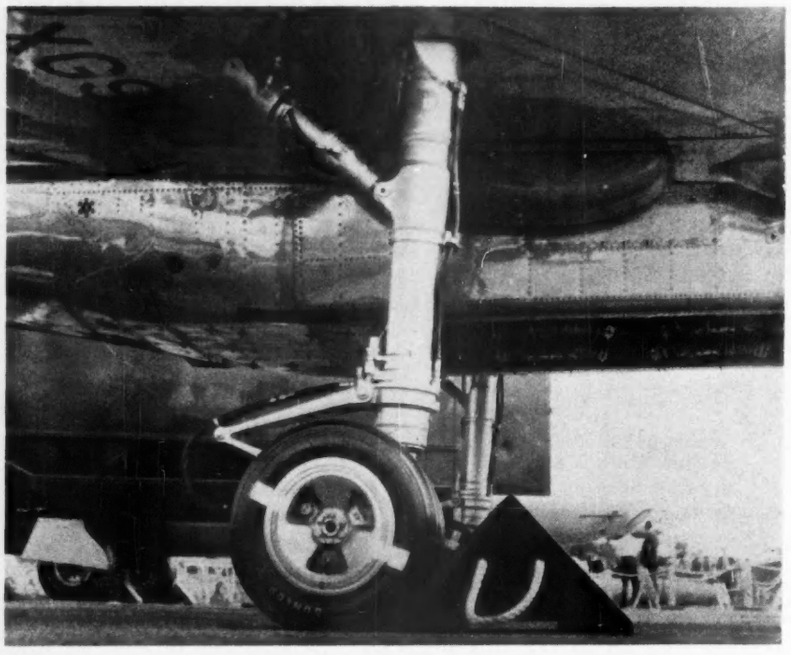
" CONSUMPTION OF SMOKE in STEAM VESSELS."

" Some short time since the owners of steam-tugs plying upon the Tyne, to the number of 150, received notices from the Inspector of Nuisances of Newcastle upon Tyne, under pain of being proceeded against for penalties under a local Act, to consume the smoke emitted by their boats, which at all times, but more especially on the occasion of busy sea tides, when from 100 to 200 vessels have to be towed out at a tide, issued from the funnels of the steam-tugs in thick volumes of the blackest density. The tug owners thereupon consulted Mr. Armstrong, of Elswick, the engineer, and, under his advice, enlisted the services of Dr. Richardson and Mr. Reed, under whose superintendence experiments have for some time past been carried on, at Elswick, to prove the practicability of consuming the smoke produced by the coal raised from the great coal-fields of Northumberland and Durham.

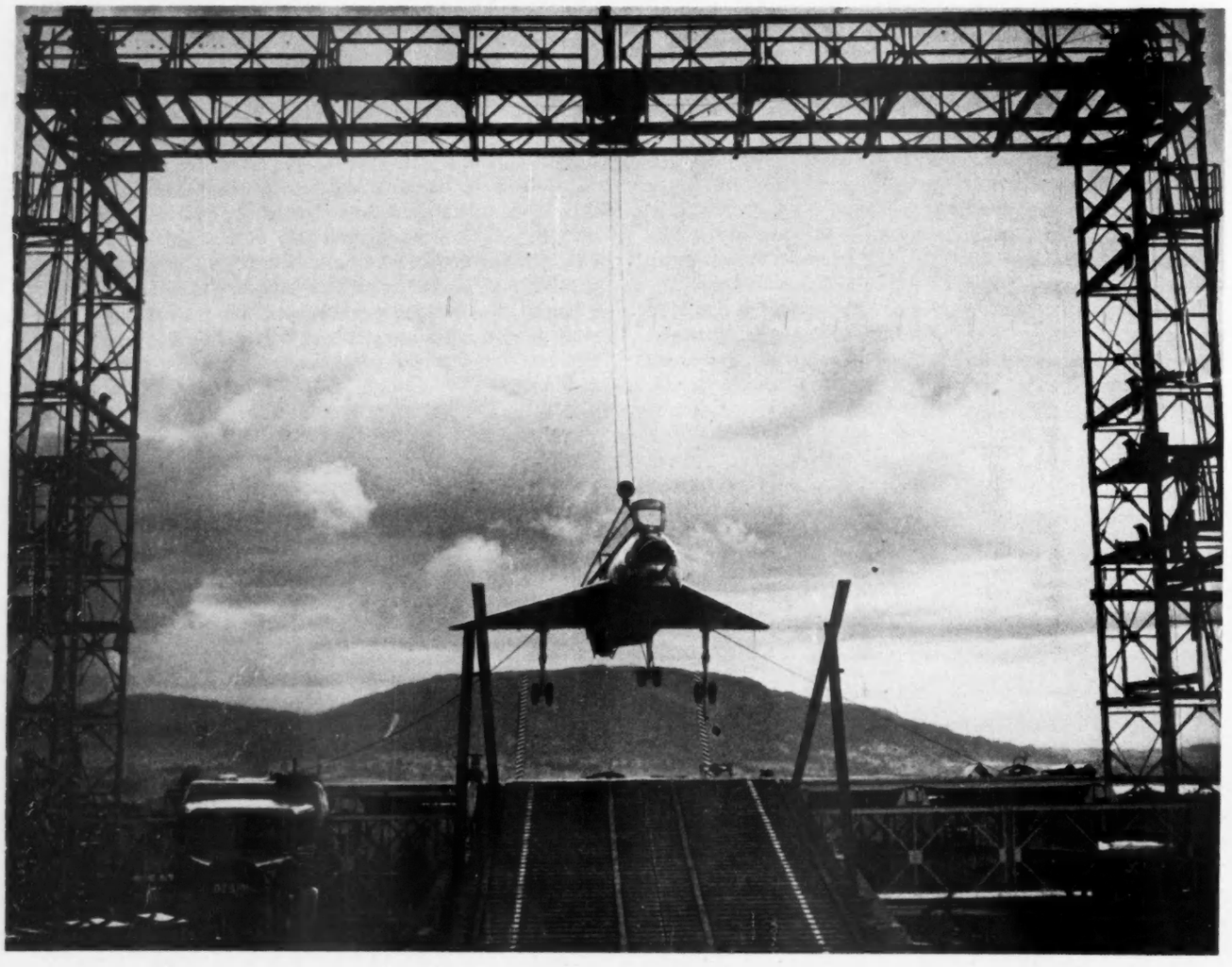
" It was arranged that one of the steam tugs should be placed at the disposal of Dr. Richardson and Mr. Reed for the purpose of making such alterations in the furnaces, as they considered would effect the desired object, and in order that, in case of success, the other steam-tugs might be altered in a like manner. The Expert, steam-tug, belonging to Mr. William Melbourne, of North Shields, was offered for the purpose, and a series of experiments were made upon the furnaces, the plan adopted being very simple, consisting of a proper admission of air into the furnace, which, combined with careful stoking, was expected to consume the smoke. After certain alterations were effected the tug was taken to sea, with the Inspector of Nuisances on board, and it was found that the improvement effected was very great, upwards of 75 per cent. of the smoke being consumed, and the remainder being of a character far less offensive, being thin and light-coloured. The inspector considered that the result was very satisfactory."

Vertical Take-off Investigations





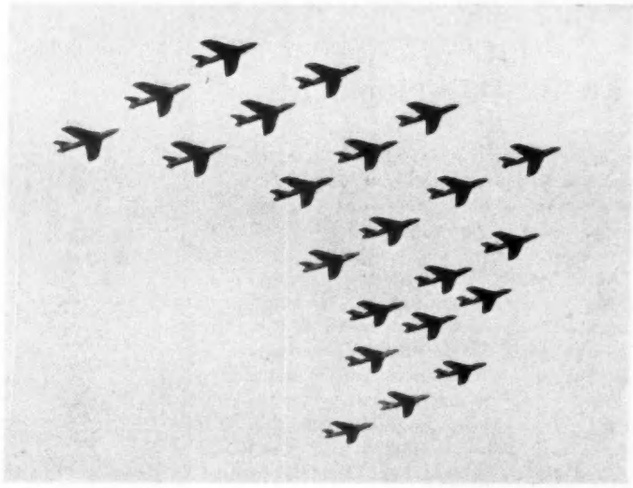
The Short S.C.1 research aircraft was seen in the Static Park ; it has flown, safeguarded but not supported by tethers, at Belfast. The picture BELOW shows it in the test gantry, guarded by the monitors of two Fordson foam tenders. ABOVE is seen the main undercarriage leg, which can be moved back for use with jet lift and forward to allow a normal nose-high take-off run ; the nozzles of the four lifting engines, which pivot in the pitch plane, can be seen. On the LEFT is the nose control nozzle ; the nozzle varies its aperture for pitch control and tilts about the longitudinal axis for yaw control. One of the fixed nozzles for roll control can be seen under the port wing tip.



S.B.A.C. Display

No. I

The 1958 Flying Display and Exhibition of the Society of British Aircraft Constructors commenced on Monday last at Farnborough ; it is open to the public to-day, Saturday and Sunday. The Royal Navy and Royal Air Force took part in the programme : here are seen "Hunter" fighters of No. 111 Squadron, R.A.F., completing a loop. We give below some impressions of the aircraft seen in the flying display and on static exhibition.



THE nineteenth Flying Display took place, on Monday, in hot calm weather with a few isolated clouds which did not interfere with the demonstrations. The first aircraft to take off were two English Electric " Canberra " variants, one, which until recently held the world altitude record for heavier-than-air machines, with a Napier " Double Scorpion " rocket motor, and the other a new product, a T. Mk. 11 with accommodation for four, including two pupils, and intended for training in the operation of airborne radar. The elongated nose ends in a sharp conical radar dome, quite unlike that of a " Javelin." The next aircraft to take off was an Airspeed " Ambassador " acting as a test bed for two Rolls-Royce " Tyne " propeller turbines ; the new engines were mounted very high in the nacelles, so that the jet pipes, which were flattened in section, could pass above the wing and no modification was necessary to the rear part of the nacelle. This " Ambassador " was an attractive example, devoid of the external butt strap joint with snap head rivets on the wing, but had fittings for a rig to spray water on to the port engine for de-icing trials. When the two turbines, each roughly as powerful as the pair of original piston engines, were opened up for take-off, the slipstream caused the tail to flap violently in the rolling plane. Both engines ran throughout the demonstration, and the landing was normal.

The Fairey " Gannet " A.E.W. Mk. 3 is extensively different from earlier marks of this aircraft. It is not only a carrier of airborne early warning equipment but also a a flying fighter control centre, and the radar mounted in a great bulge below the forward fuselage gives surveillance of sky above the aircraft itself, at a distance and in the forward hemisphere. The crew, other than the pilot, are now carried within the fuselage instead of in cockpits, and consequently the tail pipes of the Armstrong Siddeley " Double Mamba " —a more powerful version than formerly —no longer run back within the fuselage but end just below the wing leading edge. The tail fin has altered, but the two additional fins part way out on the tail plane remain, and a ventral fin, rather further forward than the other three, has been fitted ; this latter is unusual in that the forward section is hinged in the manner of a rudder so that it can be swung aside to give access to a removable hatch above it. On the prototype, which flew for the first time three weeks ago, the arrester hook was fixed in place by a jury fitting, but a spring clip to centralise it could be seen retracted. The aircraft climbed away steeply and flew past with one engine feathered ; at landing it was flown on to the runway virtually without flaring out, demonstrating the extreme energy dissipation of a carrier-landing undercarriage.

Of the several helicopters that participated, three had not been seen before : the Bristol " 192," the Saunders-Roe " P.531," and the Westland " Westminster." The Bristol " 192," built primarily for military use, is a logical evolution from the earlier " 173 " ; one of the characteristics of a gas turbine is that it can be heavily overloaded (at a sacrifice of turbine overhaul life), and thus the turbine commends itself particularly for an aircraft with multiple engines coupled together. In order to exploit this characteristic to the full, the Napier " Gazelle " engines of the " 192 " have torque meters and the control system is such that a reduction of torque on either engine, other than when demanded, automatically causes the other engine to increase power up to its overload maximum. The engines are installed, nearly vertically, one under each rotor, and the phasing shaft between them normally carries very little power, which should help to increase the airframe overhaul life even as the use of turbines should increase the engine life. The operating requirement for commercial use is that failure of one engine should allow either continuing the flight or returning safely to the point of origin ; this requirement is least restrictive if the machine rises from the ground and climbs away backwards, so if an immediate landing is necessary the pilot has a good view as he approaches forwards.

The Saunders-Roe " P.531," a light helicopter built by the firm as a private venture for emergency rescue and ambulance work and use as a trainer, exploits another virtue of the gas turbine, the improved power-weight ratio. The Blackburn-Turbomeca " Turmo " is far from being an extremely light engine, since it was not originally intended to be an aircraft main engine ; nevertheless, it has an output of 425 h.p. from a weight of 280 lb, compared to the 215 h.p. and 400 lb of the de Havilland " Gipsy " 215 in the Skeeter, from which the new machine was derived. The above-mentioned ability to overload the turbine is of value in this single-engined aircraft also ; a helicopter application requires the engine to be able to deliver maximum power for one hour, which implies that a considerable quantity of water be carried for injection into the normally-aspirated piston engine. As can be seen in our illustration, the aircraft is closely related to the " Skeeter," but four blades (identical with those of the smaller machine, on the prototype) instead of three are used on the main rotor. The tail boom and anti-torque rotor are also common to the earlier aircraft ; the cabin is much larger, so that casualties on stretchers can be loaded inside instead of out. The transmission is designed to accept the considerably greater powers that would be available from engines of higher power-weight ratio. The machine is too small for the engine to be fitted in front of the rotor, so an additional gearbox at the rear of the engine brings the output down below the rest of the plant and a shaft drive carries the power forward to the main gearbox.

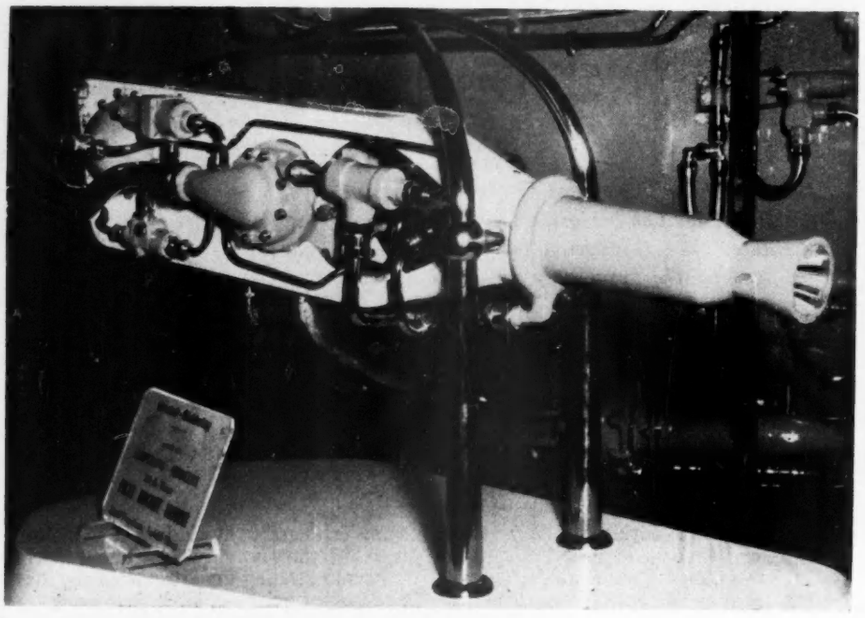
Further virtues of the gas turbine as a helicopter power plant are demonstrated by the Westland " Westminster." The " helicopter parts " of this machine are common to the Sikorsky " S.56," which has two large air-cooled radial engines in pods high up each side of the hull. The Napier " Eland " engines of the licence-built version require no cooling air and generate vastly less low-frequency vibration, with the result that they can be housed on the top of the fuselage. However, the engine nacelles of the " S.56 " also house the main wheels of the retractable undercarriage ; while one version of the " Westminster " will be a flying crane somewhat similar to the prototype (illustrated), the forty-passenger version, cruising at 150 m.p.h., will also have its undercarriage fixed, emphasising its likeness to the largest helicopter flying to-day, the " Mi.6."

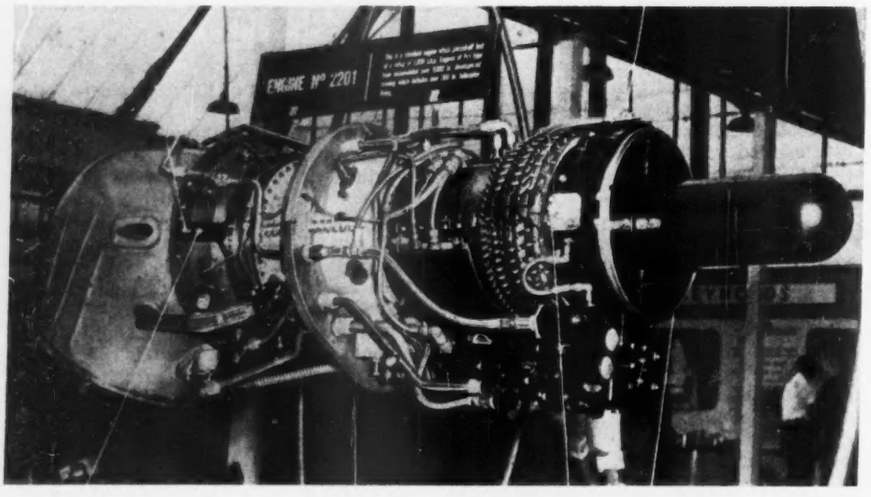
The big " flying crane " demonstrated its ability to steer at zero speed when taxying, and then took off after a run of a few yards backwards and climbed away in the same direction.

There also flew the other British production Sikorsky derivatives, the " Wessex," an " S.58 " with a Napier " Gazelle " engine, the " Whirlwind," an " S.55 " with an Alvis " Leonides Major " (earlier production machines used the Pratt and Whitney " R.1340 " or Wright " R.1300 "), and the Widgeon, an " S.51 " development with an Alvis " Leonides." Since the General Electric " T.58 " is expected shortly to be put into production in this country as the de Havilland " Gnome," it is very possible that a Westland version will follow very quickly upon the latest Sikorsky design to fly, the " S.62 " ; this has the working parts of an " S.58," but with a " T.58 " engine high up in front of the rotor pylon, so that it might be considered a less powerful and more economical version of the " Wessex " —however, it has a flying-boat hull in order to avoid any penalties in profit-earning capacity attributable to flotation gear, it being

Engine Developments

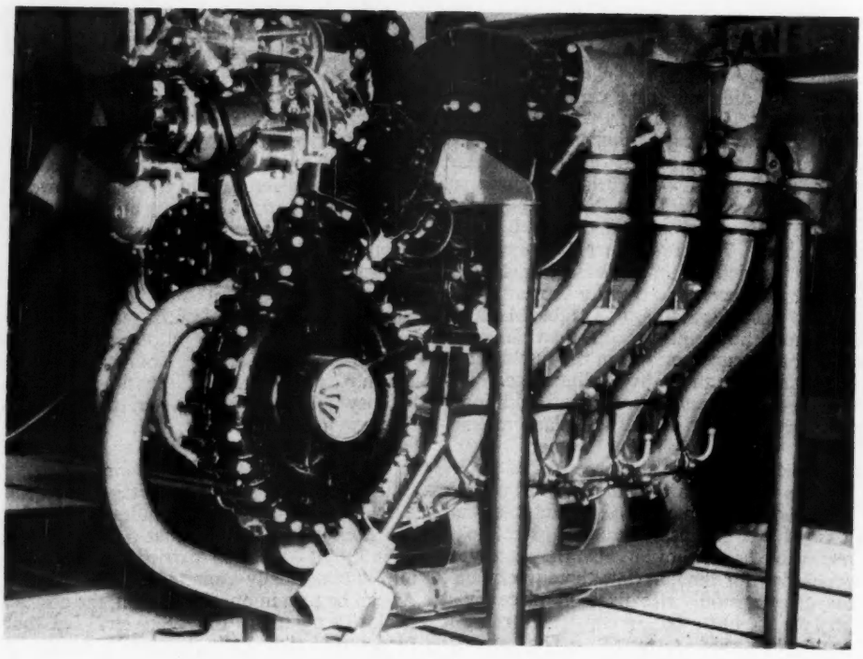
A controllable-thrust rocket motor may be the most effective or, for a ballistic vehicle, the only form of control device available, and for this purpose or as an emergency additional engine, Armstrong Siddeley have evolved the small "P.R. 23" engine, which weighs rather more than 30 lb and gives up to 300 lb thrust. This unit is seen RIGHT as exhibited: little can be said of it, but since one of the few known applications of such devices is on the vernier engines of the "Atlas," it may be that it is intended for the British ballistic missile. The "Blue Streak" is related most closely to the "Thor," which depends on its gimballed main engine for all control, but the later vehicle may have a longer range and need a more elaborate control system.





An actual example of General Electric "T-58" production was shown by the de Havilland Engine Company as a forerunner of the "Gnome" (LEFT): some of the auxiliaries fitted were of British manufacture. This extraordinarily advanced engine gives 1050 h.p. at a weight of only 250 lb, though it should be borne in mind that the distribution of masses between engine and airframe is not necessarily the same in United States and British quotations. While this engine is normally associated with helicopters, the primary reduction gear may end in a shaft running forward to a propeller reduction gear above the air intake.

Since the last war the development of compound engines has tended to distract attention from the long-established turbo-charged engine, but there has now been designed a British exhaust-turbine supercharger for use with petrol engines. This unit is seen, RIGHT, fitted to a de Havilland "Gipsy" 215: actual installations would probably have the turbo-blower beside rather than behind the engine. The turbine is an axial-flow unit, fed by separate pipes from cylinders 1 and 4 and 2 and 3 to utilise the pressure pulses: an a.b.c. unit controls a waste gate communicating with both pipes. It will be seen that the compressor handles air only, the fuel being injected into the induction ports. In a helicopter there is no propeller to swing, and a cartridge starter is included among the auxiliaries.



Two rotorcraft with twin "Eland" turbines: the Fairey "Rotodyne" with a big box-like fuselage closed by hinged doors at the rear, and the Westland "Westminster" crane/transporter, flying with a load of instrumentation. Beyond the big helicopter is seen a "Widgeon"

accepted practice to fly single-engined machines over water, if convenient, rather than built-up areas.

The "Wessex" performed "stall turns" so steep that the aircraft attitude, if not its direction of motion, resembled that in a loop; the yellow-painted upper decking was fully visible from the ground. When the four Westland machines were hovering in echelon, the two heaviest, with turbine engines, were markedly more steady than the aircraft with three-bladed rotors, seeming to be practically immobile in the still air.

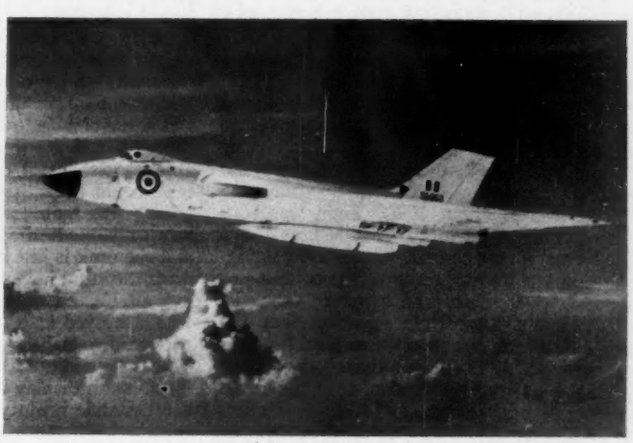
The Fairey Ultra-Light helicopter, in order to demonstrate its ability to land on difficult surfaces such as a deck on a frigate, landed on its carrier, a modified Thames platform truck, while it was doing about 10 m.p.h.; the safety nets around the sides and rear of the body carried two crew members, but they did not touch the aircraft. The helicopter leapt off the vehicle again while it was still moving.

After the helicopter flying there was a display by aircraft of the Royal Navy; it began with a take-off in very close formation by seven "Sea Hawk" fighters, the rear machines rocking in the blast of those in front as they ran up against the brakes. A large loop was emphasised by trails of red, white and blue smoke from the jet nozzles; at this stage one aircraft left the formation and the pilot abandoned it. It is, of course, accepted practice in single-engined jet aircraft for pilots to bale out on receipt of failure signals from, say, flying control systems or engine fire detectors, and this was such a case. The remaining six performed further formation aerobatics and landed, again in close formation, trailing blue and yellow smoke. During this flight six Supermarine "Scimitar" fighters arrived low and very fast, probably as near Mach 1 as is allowed in this display; however, the formation was much less steady than is usual for modern heavy, fast aircraft. Four of the big fighters then carried out formation aerobatics and one executed a loft bombing attack, a half roll off the top of a loop, an ellipse of condensation marking the lift distribution on the upper surface as it climbed sharply. It is perhaps desirable to point out that these were the only "Scimitar" aircraft on the programme; the machine was shown at Farnborough by the makers only twice, a contrast to the interval between first flight and squadron service that is accepted in some cases.

A number of transport aircraft then flew, starting with a Vickers "Viscount" of the "810" series; this was a "812" for Continental Air Lines of U.S.A., and performed with red anti-collision lights above and below the fuselage flashing. The de Havilland "Comet" 3 flew in a form designated "3B," having no external fuel tanks and the span shortened to 108ft to simulate the short-range "4B" ordered by British European Airways. Thrust reversers of the cascade pattern previously shown by Rolls-Royce were fitted to the inboard "Avon" R.A.29 jets; the burying of the engines in the wing causes there to be a deep open cavity outside the cascades. The thrust reversers were used to demonstrate a remarkably short landing run without a particularly obtrusive noise. The "Twin Pioneer" and the "President" flew again this year.

The Royal Air Force display commenced with formation aerobatics by No. 111 squadron. The first manœuvre was a loop by twenty-two aircraft, composed of three columns of three each side of one column of four, the front — and corresponding — "Hunter" of each column being in a Vee formation. Two aircraft from the outermost and one from the centre column on each side then detached, and the resulting diamond of sixteen performed a deep slow roll, in the course of which the formation became concave upward rather than flat, the machines on the outside having further to fly.

The more unusual qualities of the piloting then became evident; the diamond shed the leading seven aircraft to become a diamond of nine, so that a change of leader obviously occurred. The nine were reduced to five when four machines performed a "bomb burst" as the remainder completed a loop; at least one of the four came so low that its smoke trail was forced into the tops of the trees outside the aerodrome. The leadership again changed hands during a loop; the five aircraft began in a Vee, and in the climb the two on one arm accelerated forward to form echelon, with the erstwhile wing machine now leading. Other "Hunter" and "Javelin" fighters flew over, as did examples of the three "V"-bombers in for-



(Left) The "Victor" has been provided with external fuel tanks and a probe for flight refuelling. (Right) The "Vulcan" equipped with a guided powered bomb: the missile has fins both above and below its tail, but that below is folded towards the camera

mation ; reminiscent of displays at Hendon was a demonstration of flight refuelling, in which two " Valiant " bombers flew past with probe and drogue engaged—the making and breaking of contact was not seen.

Two of the next aircraft to take part, the Auster " Alpha " and the de Havilland " Chipmunk," gave demonstrations of crop spraying. The Auster machine had four Britten-Norman " Micronair " rotary atomisers, which by controlling droplet size far more closely than does a nozzle are claimed to cut down the amount of liquid to be deposited from the usual 5 gallons an acre to 2 gallons or less. These devices consist of a cylinder of gauze, driven by a windmill at its forward end, which acts as a rotary atomiser ; by varying the windmill blade pitch the droplet size can be varied through broad limits down as low as 46 micron mass median diameter. Each sprayer has a brake controlled by Bowden cable from a handlebar lever in the cabin ; these levers are of the kind normally associated with clutch operation, the ratchet being used to hold the brake on during ferry flights or long trips to a crop. The liquid is delivered to the atomisers under pressure by a pump, also windmill driven, underneath the fuselage. The "Alpha" trailed a voluminous cloud, more or less on a level with the atomisers, along the runway. The Mk. 23 " Chipmunk " is a variant of the de Havilland Canada trainer with a single cockpit enclosed by a crash pylon ; it has fixed slats and, as demonstrated, a conventional set of nozzles on a pipe below and behind the trailing edge.

The Saunders-Roe " P.531 " has a Blackburn-Turbomeca " Turmo " engine behind the rotor, driving by a shaft running forward below the engine. The hoist above the cabin door will be driven by bleed air

Fairey Aviation test pilots then demonstrated the " Rotodyne " and the " F.D.2 " research aircraft. The "Rotodyne" displayed all the phases of a city-centre to city-centre operation, taking off vertically and retracting its undercarriage before climbing away in the helicopter mode. At a speed of about 115 m.p.h. and at about 1000ft flight was converted to the auto-rotative mode ; as far as the pilot is concerned, this means extinguishing the tip jets, draining the compressor drive fluid clutches, and increasing the airscrew pitch, meanwhile ensuring that the angle of attack corresponds to level flight as an aeroplane. The " Rotodyne " then made a pass at its cruising speed of 185 m.p.h. and performed banked turns and a climb. Return to helicopter flight was made at about the same height and speed as the previous transition, sickle-shaped swirls of kerosene vapour showing when fuel was supplied to the tip jets again. In order, we were informed, to save time, forward speed was dissipated in a pronounced pull-up, whereas otherwise the aircraft attitude hardly changed throughout the flight ; the machine then extended its undercarriage and settled on to the grass very slowly and gently at zero speed. The tip jets were provided with " attenuators " reducing the noise about 4 dB, and in an open space the noise at full power was similar to that of a steam train at the same distance ; when flying as an autogyro the rotor thrash was audible below a typical turboprop swishing effect.

Two Folland " Gnat " single-seaters then performed, one without external stores showing remarkable acceleration from rest ; both demonstrated excellent braking when the take-off was rejected because the vehicle retrieving the braking parachute of the "F.D.2" was not clear of the runway. Both aircraft performed aerobatics, emphasising the high rate of roll of the compact little fighter. The Gloster " Javelin " F.A.W. Mk. 8 then flew ; this employs reheat, there being afterburners with very inconspicuous flame-holders far forward up the long tailpipes, so that a flicker of flame at lighting up was the only visible evidence of afterburning. The variable nozzles are of an unusual design providing virtually a restriction at the nozzle ; several segments projecting inwards through the wall are hinged about tangential axes farther forward so that they always lie roughly in the transverse plane of the jet. They are driven in or out by links from a ring moved backwards and forwards by Dunlop pneumatic actuators.

" V "-bombers followed the fighters into the air. The Handley-Page " Victor " appeared equipped for refuelling from a trailing drogue, its probe projecting forward from a point just above the centre of the pilot's windows ; there is a light on the fuselage to allow refuelling in the dark. Two large tanks were fitted under the wings. These tanks were in some ways remarkable ; they were large, probably more than 200 gallons each, and riveted from sheet, but the profile was poor, particularly in transverse section, and lent weight to the claims for plastic tanks. There were various removable panels on the tank, and an air intake under the nose. The tank was attached below the wing, projecting forward, and the join was faired by detachable panels, but it did not appear as if the tank could be jettisoned, since at the rear a fairing was mounted on the flap. There is now only one leading edge flap on each wing and the tank is just inboard of it. The flight demonstration included a low altitude bombing attack, as did that of the " Vulcan," which delayed its half roll until the loop was perhaps five-eighths complete. A " Vulcan " Mk. II carried out the demonstration, but the machine on display in the static park was the aerodynamic prototype of this variant. The principal difference from the Mk. I appears to lie in the flying controls—the earlier machine, it will be recalled, had two elevators and two ailerons on each wing, all independently power-operated, and turning about a common hinge line. On the Mk. II the inboard surfaces are much the same, but each pair was precisely in line when the aircraft was parked, as if some connection had been made between them. The outboard surfaces have a hinge line further aft, reducing their area, and have blunt, indeed re-entrant, trailing edges. Into the fixed wing area created in front of them project large mass balances, suggesting that they are no longer fully powered in all circumstances, and they appeared not only to move as ailerons but also to follow up the elevators at reduced amplitude. The wing was devoid of vortex generators. The two-spool engines of both the " Vulcan " II and the " Conway " test bed smoked heavily at high power.

There was flown over an example of the Avro powered guided bomb, carried by another " Vulcan." This vehicle has a ventral fin which folds to port into a horizontal attitude, and it remains there in flight, as our illustration shows. The explanation for this is probably that there is no method of folding it in the air, and therefore it is not extended until it is certain that the aircraft will not land with the weapon aboard. The missile appears to be about 40ft long, and the fore plane and wing are of, or close to 60 deg. delta form, suggesting a Mach number of no more than 2. However, one model displayed had the tips of the fore plane (which moves in one piece, lateral control being by ailerons at the wing trailing edge roots) cut away at such an angle as to be outside the Mach cone of the tip at quite low speeds—perhaps 45 deg. The same model also had heavy anhedral on the outer one-third of the wing. It has been stated that the Mk. II " Victor " will carry this missile ; the crescent-wing machine is so much lower on the ground that the bomb would presumably go into the very large weapon bay, but it is difficult to see how the doors, which roll outward around the axis of the fuselage, could close without fouling the wings of the store.

The Blackburn " N.A.39 " and the English Electric " Lightning " did not take part in the display on Monday, so that it closed with a flight by a de Havilland " Sea Vixen," which did not demonstrate the ability to fold its wings.

(*To be continued*)

Another Nimonic Alloy

A FURTHER heat- and creep-resisting alloy in the Nimonic series, Nimonic 105, is a development of the nickel-chromium-cobalt-molybdenum alloy Nimonic 100, mentioned on page 305, August 26, 1955. It has greater resistance to creep at very high operating temperatures than Nimonic 100, the minimum life to rupture at 7 tons per square inch and 940 deg. Cent. (1724 deg. Fah.) being fifty hours, compared with thirty hours for Nimonic 100 and fifteen hours for Nimonic 95.

An important advantage of Nimonic 105 is its improved resistance to a specific kind of high-temperature corrosion sometimes experienced in aero and other gas turbines running at elevated gas temperatures. This corrosion occurs in certain conditions of contamination by solid or molten sulphates. The fuels used in this temperature range are high-grade distillates, such as avaiation kerosene, which at lower temperatures have little or no corrosive effect. It will be appreciated that this form of high-temperature corrosion is quite different from the fuel-ash corrosion troubles met at lower temperatures with certain kinds of boiler oils containing vanadium or sodium compounds.

Nimonic 105 has already been tested by the British aero-engine industry and is now in production.

Science and Business: A Balanced Partnership

By SIR ALEXANDER FLECK, K.B.E., F.R.S.

In his address to the British Association for the Advancement of Science, delivered on August 27 at Glasgow and reprinted here in part, Sir Alexander Fleck studied how scientists contribute to a partnership with business. He concludes that there is scope for the scientist to infiltrate throughout almost the whole business structure. He also concludes, in a section concerned with education, that the gulf which at present separates scientists and non-scientists is much more easily bridged than is often imagined.

IN a population which depends so much on science, it is sad to think how few people clearly understand what it is all about. It is an approach to an understanding of the universe along a broad highway of organised knowledge firmly founded on observation and experiment embedded in a matrix of theory. It is a highway which is constantly being widened and extended and repaired. We are building it because we think that by and large it is a good road for mankind to travel, and that it is leading him away from ignorance and wretchedness towards a fuller life and a better world. Some find that the act of extending the highway gives them all they seek from their life-work : these are the pure scientists and much of our progress derives from them. Others find greater satisfaction in utilising what has already been built, pausing, perhaps, to strengthen it here, widen it there : these are the technologists or applied scientists. A few people combine both functions, driving the road forward into undiscovered territory, then paving it ready for all to use. Whatever our own work may be, we have a joint responsibility to see that the highway is properly and extensively used by all mankind. It is therefore fitting that the British Association is now devoting itself to the additional task of securing the greater use of this highway by all types of people in these islands.

Business

In this context it is easy to see the importance and responsibility of business, which produces and distributes most of our national wealth. Our capacity to extend our science and education largely depends on our ability to run business successfully. Lewis Mumford in his *Technics and Civilization*, written in the 1930s, though he appears to exaggerate their numerical importance, suggests that it may have been no accident that there were merchants of the City of London who played a part in the early days of the Royal Society. He draws attention to the affinity of science and business when he writes : " The power that was science and the power that was money were, in final analysis, the same kind of power, the power of abstraction, measurement, quantification."

I venture to put forward three characteristics which I think a business should have if it is to survive and function effectively over a period of years.

(*a*) First, it must contribute to the well-being of the community and its social evolution. I believe it can best do that in three specific ways : by producing goods or services for the community at fair prices ; by giving fair treatment in the way of remuneration and working conditions to all who give their services to the business, whether as pay-roll employees, administrators or scientific staff ; and by giving a fair return to those who risk their money in the business, so that apart from this consideration, they will be encouraged to provide again for further ventures. When business takes on itself the deployment of financial, material and human resources, it also takes on, I believe, the responsibility for seeing that they are properly and effectively used. In other words, it has an obligation to the community ; and only in so far as it fulfils that obligation does it contribute to the well-being of the community and justify its own existence.

(*b*) Secondly, business must have the capacity to change its methods and if necessary even its objectives. It must be constantly alert to see that its products or services meet or anticipate the needs of the public, and to withstand the nipping and eager air of competition whether it comes from advancing techniques or new entrants into the field.

(*c*) Finally, if it is to be self-perpetuating through growth or modernisation, a business must dispose of its products or services for more than their cost—or in plain language, it must make a profit. That is true of business whether run by private enterprise or by the State ; nor does the political system of the State make any difference to the validity of this notion. Only from the excess of income over expenditure can we finance the expansion of business and science.

This brings me again to the reason why I have chosen to talk about business rather than industry. It is an old saying that money makes money ; by the same token the production of wealth requires the investment of wealth, and such investment can come from a variety of sources. Traditionally, part comes from retained profits, that is from what economists in the past called the abstinence of the individual manufacturer, or in to-day's terms, from the undistributed earnings which companies plough back into the business. Part comes from the banks, though their function in this country has usually been to provide working capital in the form of loans and overdrafts, rather than to provide fixed capital like the industrial banks of Germany which played such a prominent part in the organisation and growth of industry in that country. To-day, by far the largest volume of capital comes from the investing public as private individuals or financial institutions, working with a vigorous and well-informed Stock Exchange.

During the past ten years the amount which the United Kingdom has invested in its productive resources has shown an encouraging growth, with the apparent result that output in manufacturing industry, as a whole, has increased by some 3½ per cent per annum since 1948, compared with about 2½ per cent between the wars. If science has laid the foundation for much of this expansion, business has provided the will and the means to complete the structure, and both must continue to do so.

There is another reason why it is important that this partnership should continue to flourish. We have in these islands over 50,000,000 people who enjoy a material standard of living surpassed in few other countries in the world. Our mineral resources are limited and indeed declining. It is by means of the goods produced by manufacturing industry and the services provided by finance and commerce, in short by business as a whole, that our 50,000,000 are enabled to live, and on the whole to live tolerably well, in an area too small to feed them, at least by present methods. All this is commonplace, but like much that is commonplace, it is easily taken for granted until we remember that over 90 per cent of the world's population live in countries less prosperous than our own, most of them in conditions that we should not dream of tolerating. The world does not owe us a living ; we can only enjoy the standards which our business enterprise and scientific knowledge enable us to earn through our exports.

Our old staple exports of textiles, iron and steel, and coal, have long since given way to newer lines, vehicles, aircraft, machinery, chemicals and electrical goods. Even here the pattern keeps changing. Motor vehicles, fine and heavy chemicals and so on, are increasingly being manufactured in countries which previously produced only food or primary raw materials. In India, I am told, a company manufacturing diesel engines and electric motors is exporting 30 per cent of its output. Chemicals from Red China and mass-produced toys and torches from Hong Kong are met in many of the world's markets. We are therefore obliged to rely either on selling things which no one else has yet learnt to make, or make as cheaply, or on marketing our skill and know-how.

It is not difficult to find examples of what happens to our business when " Rule of Thumbism " is preferred to operations guided and controlled by science and technology. I think there would be general agreement that at various times some of our traditional industries in which we were pioneers have suffered from the lack of proper scientific direction. In my own industry, organic chemicals once experienced the same neglect. The lead that Perkin had given to our synthetic dyestuffs industry with mauveine, was frittered away through lack of scientific effort.

The lesson has not yet been fully learned. I have a quotation here from a Managing Director who went on record last May. The scope of his company may be small and may be provincial, but that the sentiment still exists in minds capable of directorial control is significant. He writes : " The place of the expert is not in the saddle, but as the assistant and the adviser . . . . The scientist must be on tap, not on top." Such a relationship is very different from the partnership of science and business that I have in mind.

A Balanced Partnership : How to Achieve It

(*a*) *The Scientist in the Business Structure.*—Research applied to business can take different forms, and I think you may be interested in one example within my experience. It began with a research manager's conviction that a new inhalant anæsthetic was needed which should have the following properties : it should be a volatile liquid, with high anæsthetic potency, and be free from toxic, explosive and fire hazards. These criteria, he argued, pointed the way to aliphatic halogen compounds containing little hydrogen and especially to compounds with two or three fluorine atoms on the same carbon atom

—groupings which are known by organic chemists to be not only unreactive in themselves, but also to strengthen neighbouring carbon-halogen bonds. The resulting inertness is one of the factors in avoiding toxicity ; and the use of fluorine rather than other halogens keeps the volatility high. He also proposed a new method of expressing dosages which made it possible to relate, by using a principle of chemical thermodynamics, the amount of anæsthetic in the inspired air to that in the body fluids. This helped in the selection, for biological testing, of compounds likely to have the desired potency, among which the one finally chosen was 2-bromo-2-chloro-1 : 1 : 1-trifluoroethane, a new compound synthesised specially for the purpose.

The major research effort, which for the first two years fell to the organic and physical chemists, had at this stage passed to the pharmacologists, whose screening tests took some three years. They showed that the new compound had not only the properties sought, including a high margin of safety from overdose, but also some unexpected advantages. Clinical trials with successful results began six years after the research started, and meanwhile manufacturing methods were developed by chemists and engineers, leading to general release to the medical profession two years later.

There are several features about this much abbreviated story, some of which are relevant to my present theme. It illustrates, first of all, the systematic application of pure scientific principles to a desired and well-defined end, which, though primarily commercial, is not without social implications. Second, the research threw light on the physico-chemical basis of anæsthesia, which time, if no other reason, forbids me to enlarge upon. Third, success was crucially dependent on the existence of a team of specialists in several scientific disciplines and also in the somewhat recondite technology of fluorine ; notwithstanding these favourable circumstances and adequate financial backing, the research and development took seven years. Fourth, the distinction between the research and the development function of business is brought out : the original synthetic and early testing work was research, while the development consisted of devising suitable methods of manufacturing and launching the chosen compound, and of studying its clinical effect.

I now turn to the functions of design and construction, which are essentially the field of the technologist or engineer. His grasp of scientific principles, combined with the creative skill of a Telford or a Fowler, fits him above all to build a bridge between science and business. It has been said : " The establishment of the class of engineers . . . is the more important because this class will, without doubt, constitute the direct and necessary instrument of coalition between men of science and industrialists, by which alone the new social order can commence." These words of Auguste Comte remain as fresh and as true to-day as when they were written over a hundred and thirty years ago.

The production or operation function includes the application of technical methods often according to routine, though it also demands much planning and organisation. Although such work is sometimes considered humdrum and repetitive compared with research and development, it is often essential for it to be done by highly qualified technical men. It is just as great a mistake to believe that unqualified men who come up what used to be called " the hard way," are generally adequate, let alone best for production work, as to hold that good technical people are wasted in such jobs as plant management. On the contrary, they must be encouraged to regard it as an interesting and necessary part of their training for higher management.

If there are to be no weaknesses in any one part of the organisation, technical staff may have to be moved from one department to another, and this places a vital responsibility on those exercising the personnel function in selection, training and promotion ; at the same time it is their duty to ensure that employees can find satisfaction in their work. This function also can be conveniently performed by a scientist, whose knowledge of what the technical departments require, helps him to place staff to the best advantage both of the business and themselves.

On the commercial side also, scientists may be needed in sales, sales service or purchasing, to achieve the best results for a business making technically complex products. I cannot agree that employment of technical men in commercial departments is necessarily wasteful : it gives flexibility within the business, and can often ensure smoother co-operation when a works manager or research chemist feels that his own, the technical point of view, is understood by a man in one of the commercial departments ; moreover, as training for higher administrative posts, commercial experience is invaluable to the scientist.

When he reaches such a post, the scientist, recognising the value of science in business administration, will be well placed to exploit it. I am not thinking here only of new equipment in the office, such as electronic computers or apparatus for sensing letters and figures ; science has more to offer than mere tools. It offers the whole philosophy of the scientific approach to the problems of management. I need only remind you of some of the steps involved : definition of the problem, observation and collation of the relevant facts, formulation of a hypothesis or principle, its testing and its general application.

This approach has been of untold value in the examination of human activity and its measurement, which is usually described as work study. It has also been very successfully employed in the problems of supply and distribution, in adjustments of stock levels and in planning of delivery programmes. The full application of such methods usually involves some specialist techniques, especially of a mathematical kind, but even the first qualitative steps of the scientific approach can often lead directly to improvements in business efficiency. All the same, it is worth noting that an otherwise successful application of such techniques can founder on the inability to handle human relationships with proper understanding.

(*b*) *Balance in Education.*—There are three senses in which we might consider balance in education. The first arises from two different conceptions of the purpose of education. On the one hand there is the formation of character, and the development of intellect and personality. At the other extreme is the concept which I suppose finds its most powerful expression in the educational philosophy of Soviet Russia, that the purpose of education is to provide useful members of society in which the desires of the individual must be subordinated to the needs of society.

I do not believe that these two concepts are wholly conflicting nor that the second runs completely counter to the British tradition of individual liberty. A balanced educational system should have room for both. The striking successes achieved by the Russians in science and technology are directly attributable to a system of education deliberately designed to produce large numbers of technically trained men and women with the ability to increase the economic power of the country through industrialisation. To this end they established a strong teaching profession to which recruitment is no problem because it enjoys the highest pay and status of all the professions. Though undoubtedly State direction still has a place in the Russian educational system, its purpose is being achieved to an increasing extent by incentives.

We are proud that our Universities, despite their growing financial dependence on the State, still retain their academic independence intact. Nevertheless, they have quite properly reacted to the stimulus of the country's needs, which have led the older Universities, for so long the home of the humanities, themselves to enlarge their science faculties. The new St. Catherine's College at Oxford and Churchill College at Cambridge will give particular prominence to the study of science. The introduction of transfer scholarships to enable promising arts men to turn to science, has been readily accepted. More sixth-formers are reading science in Public and Grammar Schools. Some long-term financial incentives may operate here, but more important has been an intensive propaganda effort which I hope will be sustained by this Association's programme for organising lectures up and down the country on the lines of those so successfully pioneered by the Royal Institution in London.

This brings me to the second sense in which I refer to balance in education. I am thinking here of the need for those who study the humanities to have some understanding of the workings of science, and for our scientists to widen their horizons by relating their science to its human context both historically and in terms of the present day. I have in the past on several occasions declared my belief that the gulf which at present separates our scientists and non-scientists, is much more easily bridged than is often imagined. For example, the qualities of mind which are fostered by studying chemistry and history are very much alike. Both chemists and historians must cultivate an inquisitive and acquisitive mind. Both need to exercise judgment, leavened with a good measure of scepticism in the exemplary tradition of Robert Boyle. Both must be imaginative, the chemist in advancing hypotheses to predict the future, the historian in doing so to explain the past.

The merits of a balanced curriculum are recognised in Soviet Russia, where children between eleven and seventeen devote something like 46 per cent of their working hours to science subjects, with the emphasis predominantly on mathematics, and another 46 per cent to what we call arts subjects, with the emphasis here on Russian language and literature. Clearly a correct balance can never be achieved with premature specialisation, which the current demands for entry into many Universities impose on our most talented students.

There is a third and final sense in which I refer to balance in education. I have said that we demand, from our scientists and non-scientists alike, intellectual qualities, such as curiosity, judgment and imagination. Equally, we want our young people, whatever their branch of study, to possess high qualities of character. I need not enlarge on this theme except to say that the society which a balanced partnership of science and business can help to build, will as always call for courage, integrity and tenacity. These are some of the ideals that we might have in our minds, as we each address ourselves to the problems of education for an age of science.

Thermonuclear Research

At the Glasgow meeting of the British Association on September 1, Dr. T. E. Allibone, F.R.S., addressed the gathering on some aspects of research on the control of thermonuclear fusion reactors. An abridged version of the lecture follows.

At our Dublin meeting last year, Mr. Lawson and Sir George Thomson reviewed the way by which reactions between hydrogen nuclei might be caused so that useful power could be generated. From data on the reaction cross section for deuterium ions it is obvious that they must have energies of tens of kilovolts in order to have a reasonably high fusion probability and the ions must be maintained as a hot gas at temperatures of over 100 million deg. for quite long periods of time. Mr. Lawson drew our attention to the fact that such a hot gas does not lose energy by radiation according to the Stefan-Boltzmann law which applies to black bodies, and which depends on the fourth power of the temperature, but instead, and indeed fortunately for our present purpose, loses energy only according to a square root function of temperature. He spoke of a critical temperature for a volume of this completely ionised gas as that at which the rate of release of fusion energy just exceeds the radiation loss ; for the deuterium D–D reaction, this T_c is of the order of 10^8 deg. and for the D–T reaction is three times lower. Even these temperatures are based on retaining the products of the reaction until their energy has been absorbed in the gas ; if, however, some products escape, as in practice the uncharged neutrons must do, the critical temperature will be higher. If all the reaction products escape, the inefficiency inherent in converting their energy into electricity to maintain the system sets a lower limit on the product of the density of the gas and the time for which it must be kept hot. In this case short transient methods are ruled out: the densities needed are unpracticable.

Sir George Thomson reflected upon the ways in which a hot gas might be held together without destroying the vessel containing it and quickly dismissed several nice ideas which cannot be made to work, ultimately coming down in favour of the pinch effect method in which the electromagnetic forces associated with a high current discharge pull the gas away from the walls and compress it into a narrow cylindrical channel. Such pinched discharges have instabilities and he suggested ways of controlling them.

The year since we met in Dublin has seen the achievement of some discharges in deuterium carrying high currents for relatively long periods of time, held in reasonably stable positions, and in a number of these discharges neutrons have been produced copiously. In this country all our efforts have been concentrated on the method of approach involving the pinch effect in a high current discharge, and in other countries, too, this method has received the most attention. Other methods are being studied ; thus, for example, the American Atomic Energy Commission recently announced three main projects involving other methods.[1] In the work at Livermore and Oakridge laboratories the hot gas is contained essentially in a cylindrical vessel with a very large magnetic field running parallel to the axis. This field makes the radial diffusion and heat conduction in the gas very small. Losses in the longitudinal directions are prevented by making the magnetic fields at the ends of the cylinder still larger and the resulting constrictions of the lines of forces at these points act like magnetic mirrors and reflect charged particles which approach the ends. Such devices are known as " Mirror Machines " or " Pyrotrons " and their field configuration will contain a hot gas effectively provided the number of particle collisions is small. Fortunately, this is the case at temperatures of 10^8 deg., but it is not true at low temperatures. In this method, therefore, the experimenters aim at generating initially a very high temperature but low density gas, and then raising the density. This is in contrast to the pinch effect approach which starts with the required density and raises the temperature.

In the third project—Project Matterhorn at Princeton University—a large magnetic axial field is again used to prevent radial losses, but in this case the end losses are overcome by bending the cylindrical tube into a torus, and thus eliminating the ends. The magnetic lines of force run parallel to the tube and around the circumference of the torus. Unfortunately, such a toroidal magnetic field has a larger magnitude near the inside wall of the torus than near the outside wall. The variation in magnitude would cause a transverse diffusion of the charged particles, and this effect has been overcome in the " Stellerator " by twisting the torus into a figure-of-eight shape.

In addition to the different magnetic field configurations which are being used to achieve containment of the hot gas, there is also a choice in the way in which to heat the gas. The various methods are ohmic heating due to electric currents in the gas, adiabatic compression, heating caused by alternate irreversible compressions and expansions, shock waves, and the injection of energetic charged or uncharged particles. Ohmic heating is generally associated with the pinch effect approach, and at first sight it looks the most suitable method of dissipating very large powers in the gas. The snag is that the electrical conductivity varies as $T^{3/2}$ and at 10^8 deg. it is twenty times better than copper, and hence very large currents are needed to generate a required power. It is because of this that other methods are being actively studied. In the case of the Mirror Machines the main heating method being studied is the injection of fast particles since here energetic gas particles are required from the start.

I will concentrate on giving you details of the pinch effect method. This is justified since it is the main method being studied and because it is the method which has yielded such interesting results in the past year.

We owe to Sir George Thomson the original concept of using the pinch effect in a gas discharge in a toroidal vessel as a way to contain the hot plasma and keep it from the walls of the vessel. By making the discharge curl up on itself in such a torus, end effects at electrodes are avoided. During the war Steenbeck in Germany had produced such a toroidal discharge carrying a few thousand amperes, but his goal was to produce high-speed runaway electrons as in a betatron, not to achieve high temperatures as such. Thomson set Alan Ware to work on this problem in 1947 and in a short time Ware had generated currents of 30,000A in a 16in diameter glass torus having a bore of 1¼in and was the first to show a marked pinch effect in a gas discharge.[2] He was using a 2000-joule bank of condensers, and examined the discharge with rotating mirror camera, thus showing it to pinch to narrow diameter in 2 or 3 microseconds and then expand again, from which he concluded that the inertia of the rapid contraction was causing the discharge to constrict beyond the equilibrium position and hence " bounce " out again. Further contractions and expansions followed. When the energy fed into the discharge was increased spectroscopic observation showed that the walls were evaporating as the discharge struck them, and both glass and quartz tori evaporated.

In Oxford Dr. Thonemann was conducting similar experiments on gas discharges independently and in 1951 his work was transferred to A.E.R.E., Harwell, and Ware's to A.E.I., Aldermaston. Since that date the two teams have been built up working in close collaboration, the work in Aldermaston having been supported by a Government contract, and the work generally planned on a joint basis. As far as we know there had been no similar work in America or Russia up to this date.

In 1951, the first metal torus was made in Aldermaston in aluminium to try to avoid the troubles due to fracture of glass and to conduct away the heat pulse to avoid evaporation. Two gaps were provided in this first torus to prevent the metal tube from acting as a short-circuited turn, and they were bridged by insulating rings shielded in some measure from direct radiation from the discharge channel. Discharges of many thousands of amperes in hydrogen were produced but arc discharges bridged the gaps and many attempts were made to avoid this. Tori having very many porcelain spacing rings were tried, and one torus, with tube bore 30cm and torus diameter 100cm, tested in 1955 during the Geneva Conference, carried 100,000A in deuterium gas for 200 microseconds. The discharge pinched to narrow diameter and remained so, but was subject to violent lateral movements. Counting apparatus was set up but no neutrons were detected.

In 1954, Kruskal and Schwarzschild derived a theory of the instabilities which must arise in a gas discharge pinched by its self-magnetic field. If any kink develops due to any geometrical or electrical irregularity, the surrounding magnetic field exerts a greater pressure on the inside of the kink than on the outside, the pressure varying inversely as the radius of the kink curvature and the kink grows in amplitude. Carruthers and Davenport (1957)[3] had observed these instabilities in A.E.R.E. a year before this theory was published : they had been using straight tubes and also a torus 30cm diameter, 10cm bore, pulsed for 500 microseconds with currents in argon and krypton, and observed the discharge with an image-converter camera at different moments during the pulse. They showed that after the current channel has pinched it becomes unstable and assumes a rapidly fluctuating helical configuration having a helical pitch several times the dimension of the bore of the tube. Hemmings, Miles and Ware (Venice, 1957)[4] showed that in argon the instability grows with a velocity of 5×10^5 centimetres per second. In hydrogen they grow at a faster rate, and at high current velocities up to 10^7 centimetres per second have been observed.

Unknown to us in England at that time, Artsimovich with collaborators in Russia had been experimenting from 1951 with straight discharge tubes, and so had a number of American scientists. Straight tubes have the experimental advantage that with them it is much easier to obtain high currents and

high rates of change of current than with toroidal tubes. They have the disadvantage that there is no heat insulation from the end electrodes and after a short period metal vapour must enter and quench the discharge. Because of this such tubes are never likely to be used in a final thermonuclear reactor. The Russian investigators used transparent discharge tubes, porcelain tubes, and metal tubes up to 60cm. diameter, and up to 2m long, and passed currents up to 2,000,000A in various gases and with rates of rise of current up to 10^{12}A per second and used a bank of condensers conserving up to 250,000 joules. These currents and rates of rise of current were much greater than we had used. They had observed (by 1956, April, the date of Kurchatov's lecture in Harwell)[5] rapid pinching of the discharge followed by expansion, then further contractions and expansions, and finally blowing up of the discharge. The associated variation of inductance caused corresponding fluctuations in the discharge voltage. Quite early in these experiments, in 1952 according to Kurchatov, neutrons were found in deuterium with gas pressure of 0·1mm and at currents over 400kA, the neutron yield increased rapidly with peak current. At first these were naturally thought to be due to D–D reactions in the gas in equilibrium at high temperature as expected with such large currents, but doubt was cast on this when later the investigators found they could detect neutrons at 150kA, and Artsimovich later showed that the yield, rising ten times between 220kA and 400kA, ceased to rise with higher currents. The neutrons appeared as bursts of about 10^7–10^8 at the second and third kinks of the voltage oscillograms, and were eliminated if 0·01 per cent of gas impurity was added to the deuterium. Although their source was somewhere along the length of the gas discharge and not concentrated near to the cathode, a study of the energy of the neutrons showed that the reactions were caused by deuterons with energies of 50–100keV directed parallel to the tube axis. This proved the reactions were not thermonuclear in origin.

In very similar work at the Radiation Laboratory of the University of California which started at about the same time but was not published until the Venice Conference of 1957,[6] much the same results were obtained. The research workers there also went through the stages of initial exaltation, growing doubts, and finally experimental proof that the reactions were caused by directional acceleration of some of the deuterons. Various theories have been put forward to explain how some of the particles are accelerated to energies greatly in excess of the applied voltages. The most convincing is that due to Colgate. An extension of Kruskal's theory shows that there is one mode of instability in which the discharge over-constricts at some places along its length and expands at the points in between. This instability is known as the "sausage" instability, and the rapid change of inductance at the points of constriction can cause large local voltages. A few of the particles can traverse these regions and gain high energies. Some photographic evidence that this form of instability exists in practice has been obtained at the University of California.

By 1954 it was clear to us in this country that there were two main problems which had to be solved before the pinch effect approach could be expected to yield high temperatures; one was the discharge instability and the other the vaporisation of the tube walls. Of these the former was recognised to be the more fundamental, since no material could be expected to withstand the

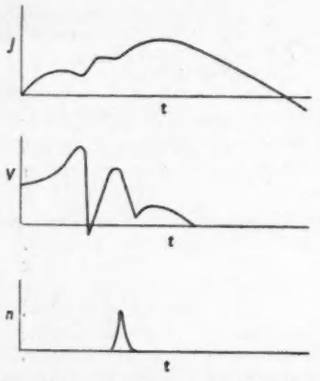


Diagram of time variation of current and voltage in linear discharge, showing also the burst of neutrons

bombardment caused by the close approach of an unstable and hot discharge. On the other hand the development of suitable materials to withstand the radiation and limited bombardment from a stabilised and well contained discharge could be expected. In the subsequent years many experiments were carried out with extra electromagnetic fields applied to the discharge in order to control the instability. The most obvious field to try is a steady toroidal magnetic field running parallel to the discharge since many earlier workers with low current arcs had found that axial fields anchored the discharge in one position. The experiments, however, presented a picture far from simple (Hemmings *et al.*, loc. cit.). In many cases the magnetic field destroyed the pinch effect and in other experiments at lower fields there was evidence of increased instability.

With further experiments our understanding of the behaviour of such discharges in the presence of magnetic fields improved, particularly as a result of the contributions of Bickerton and Tayler at A.E.R.E. and Liley at A.E.I. It was realised that an axial magnetic field inside the discharge would give the discharge stiffness and prevent the growth of sausage instability and short wavelength wriggle instabilities. On the other hand, an appreciable axial magnetic field on the outside of the discharge is detrimental in that it encourages the growth of certain modes of the wriggle instability. A field configuration was therefore required in which there was an axial magnetic inside the discharge but little or none outside. Lastly, in order to achieve complete stability it was necessary to combine this configuration with a metal tube whose eddy currents would suppress the long wavelength wriggle instabilities. The exact requirements for stability came as a result of careful mathematical analysis by Tayler in 1956 (see Tayler, 1957).[7] Rather surprisingly the same results were obtained independently at almost the same time by Rosenbluth in America (1957)[8] and by Shrafranov in Russia (1956).[9]

Fortunately, Nature has made it fairly easy to obtain the magnetic field configuration required for stability. This is because, if a discharge is created in a metal tube with an axial magnetic field, the radial contraction of the discharge across the field causes currents to circulate in the gas which enhance the magnetic field within the discharge. This increase of magnetic field causes further currents to circulate in the opposite direction in the metal tube and the magnetic field of these currents cancels the applied magnetic field outside the discharge. This effect is known as field "trapping" since the contracting gas appears to carry the magnetic lines of force in with it.

The first published experimental work describing the observation of magnetic field trapping was that of Bezbatchenko *et al.* described at the 1956 Stockholm Conference.[10] Fields up to 12,000 gauss were applied to discharges of the type already referred to by Artsimovich. Four main effects may be mentioned: (*a*) the degree of contraction of the plasma diminishes as the applied field is increased in value; (*b*) the rate of contraction diminishes, and oscillograms show that the rapid rise of potential across the tube due to the rapid increase of inductance no longer occurs when fields of 8000 gauss are imposed; (*c*) after the initial radial oscillations of the plasma, without the field the discharge rapidly blows up and reaches the walls, but with the field the expansion is retarded; and (*d*) the measurement of the flux with magnetic probes shows that the conductivity of the plasma in the first stage of the pinch, say for 3 microseconds is insufficient to trap all the longitudinal lines of force, but rises rapidly—by two orders of magnitude—in the following 3 microseconds during which no further escape of the field occurs. All the Russian work reported concerns discharges lasting for only a short time; after 6 microseconds the peak current has been passed and records are not available. No reference is made to the effect on the neutron yield.

The American investigators (Anderson *et al.*, loc. cit.) applied up to 100 gauss longitudinally and report only the effect on the neutron yield; the yield falls off inversely with field and is zero at 100 gauss; calculation showed that the internal pressure of the field prevented the discharge from constricting to the radius necessary for the longitudinal accelerating voltages to reach high value. Most recent results in America (Burkhardt *et al.*, 1958,[11] Hagerman *et al.*, 1958[12]) confirm that in straight tubes carrying currents of 10^6A for a few microseconds, fields of 1000 gauss prevented pinch instability but also greatly reduced neutron yields; small amounts of impurities also reduced neutron yield—it will be seen later how this stands in marked contrast with results on long duration discharges.

In England, a discharge with the trapped magnetic field configuration was first observed by Bickerton in 1956 (Venice, 1957).[13] With a metal torus (diameters 30cm and 10cm) large currents were studied in hydrogen lasting for hundreds of microseconds in the presence of axial fields of several thousand gauss. Magnetic probe measurements indicated that the discharge was stable. After 170 microseconds, for example, the axial field is greater than the applied field in the centre of the discharge and less at the walls of the torus, and from the measured value of the self-magnetic field of the discharge, the current distribution over the cross section of the discharge can be derived; this shows the current to be carried on a hollow cylinder of about one-third of the diameter of the torus. A plot of the contracting force $i_z B_\theta$ and the outward force $i_\theta B_z$ shows that they are roughly equal and opposite at all radii. Unfortunately, the stabilisation theory of Tayler (loc. cit.) shows that the discharge of 27kA should be pinched but not stable; however, theory makes several simplifying assumptions such as infinite electrical conductivity, which are not true in practice. In this particular case the enhanced magnetic field in the discharge may have been due to a paramagnetic effect in the gas rather than to field trapping.

In August, 1957, in the apparatus known as ZETA at A.E.R.E., neutrons were detected for the first time from a toroidal discharge (Thonemann *et al.*, 1958),[14] and shortly afterwards similar results were obtained with

SCEPTRE at A.E.I. (Allen *et al.*, 1958)[15] and PERHAPSATRON at the University of California, Los Alamos (Housaker *et al.*, 1958).[16] The sizes of the toroidal tubes varied widely in these experiments, thus ZETA is an aluminium tube with bore 100cm and torus diameter 300cm, SCEPTRE is an aluminium tube with diameters 30cm and 115cm, and PERHAPSATRON is a metal sheathed quartz tube with diameters 5cm and 32cm. In all three cases the results showed that stabilised discharges had been obtained with trapped magnetic field configurations. In ZETA and PERHAPSATRON magnetic probe measurements showed the enhancement of the axial field within the discharge and reduction near the walls, and the measurements were free from the major fluctuations associated with instability. With SCEPTRE, measurements of inductance from the rate of change of current indicated the discharge leaving the walls and constricting when the self-magnetic field equals the applied magnetic field, as expected when trapping of the field occurs. In addition, a photo-electric time and spatially-resolved study of the light from highly ionised impurity atoms showed the light came from a narrow core which always remained in the centre of the tube. With ZETA and SCEPTRE the discharge was held stable for long periods, namely 2 and 0·5 milliseconds respectively.

The currents studied in these experiments were in the range of 5×10^4 to 2×10^5A, and in all three cases neutrons were observed at higher currents. The nature of the neutron emission was very different from the early work with linear discharges. Thus, neutrons were emitted throughout most of the current pulse and not in short bursts. An axial magnetic field was necessary for neutrons and in each case maximum yields were obtained at approximately that magnetic field which would limit the discharge constriction to one-third of the tube diameter. With 25 per cent nitrogen impurity in ZETA some neutrons were still detected and with SCEPTRE 10 per cent argon produced only a small reduction in yield.

In general, the results with the three experiments follow simple scaling laws which confirm the theory of the stabilised discharge. Thus the time constants are proportional to the square of the tube radius (b^2), the pressures proportional to $1/b^2$ and magnetic fields proportional to $1/b$. The number of reactions per unit volume is proportional to $1/b^2$ whereas the number of reactions per unit length of tube is independent of b. Since, in addition, the energy input per unit length is independent of b, the three experiments are equally efficient in producing neutrons.

With ZETA and SCEPTRE measurements were made to determine the ion temperature in the gas. This was done by observing the Doppler broadening of the spectral lines of impurity ions in the discharge. The shape of these lines was found to be consistent with the atoms having a Maxwellian distribution of velocities and a temperature of several million deg. It was not proof of the temperature, however, since a random instability or wave motion in the gas could have mass velocities which, averaged over time, give a Maxwellian distribution. Nevertheless, these ion temperatures were found to agree reasonably well with those which would be needed to produce the observed neutrons by thermonuclear reactions. This fact, together with the marked differences in the observed neutrons compared with the linear discharge made the scientists involved fairly confident that they had observed true thermonuclear reactions. Further confirmation was given by the fact that a theory of the ohmic and adiabatic heating by Liley at A.E.I. predicted temperatures of the order observed (see Allen *et al.*, loc. cit.). Such was the state when the announcements were made in January of this year.

In the subsequent months further measurements began throwing doubts on these conclusions. In many cases the Doppler broadening and neutron "temperatures" were found to differ quite widely and what evidence there was of the electron temperature suggested that it was below 1,000,000 deg. The apparent ion temperatures indicated a gas kinetic pressure comparable with the magnetic pressure, and this was inconsistent with the inductance measurements. Following this the scientists at A.E.R.E. were successful in performing the difficult experiment of measuring the neutron energies (Rose *et al.*, 1958).[17] This showed conclusively that the neutrons were not thermonuclear! The reactions were being caused by a few of the deuterons being accelerated parallel to the discharge current to energies of 17keV. Once again, therefore, Nature appears to have fooled the scientists, this time in a rather more subtle way.

This discovery has been a great disappointment to the scientists concerned. I must point out, however, that the evidence for a stable discharge maintained for a long period still stands, and this in itself is a major advance; just over a year ago the instability problem was the main problem holding up progress. The big questions which now have to be answered are—what are the true ion and electron temperatures in ZETA and SCEPTRE, and how is the heat generated in gas being lost to the walls?

There are several features of the results which are not understood; for example, high-speed photography shows bright bars of light travelling along the tube. These suggest some form of wave motion and they may well present a mechanism for heat loss to the walls. Again arc breakdowns still occur at the gaps in the metal torus in the case of ZETA and SCEPTRE, although it is much less severe than in the presence of an unstable discharge. This arcing is thought to be the cause of the impurities observed in the discharge, and the arc spots which travel along the inside surface of the tube may provide paths for heat conduction losses to the walls. Perhaps the next advance will come through improved materials for the tube walls. If the arc breakdowns can be avoided—and we are conducting research to achieve this—the major heat losses may be removed.

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"MOGUL" LOCOMOTIVE PRESERVED

AN American correspondent sends some interesting details concerning a "Mogul" engine which has recently been preserved. This engine, the "Glenbrook," No. 1, is a wood burner, built in 1875, and around that period it was employed on lumber hauling between Spooner Summit and Glenbrook, Lake Tahoe, Nevada. This old veteran has now been reconditioned and placed on a short length of track, and put in permanent public preservation, in the Nevada State Museum at Carson City. The correspondent says the engine is in a very good state of preservation. He also asks if there are any "Mogul" type engines in preservation in this country or in Ireland, and, if not, this may well be the only instance of a "Mogul" type engine being preserved in the world.

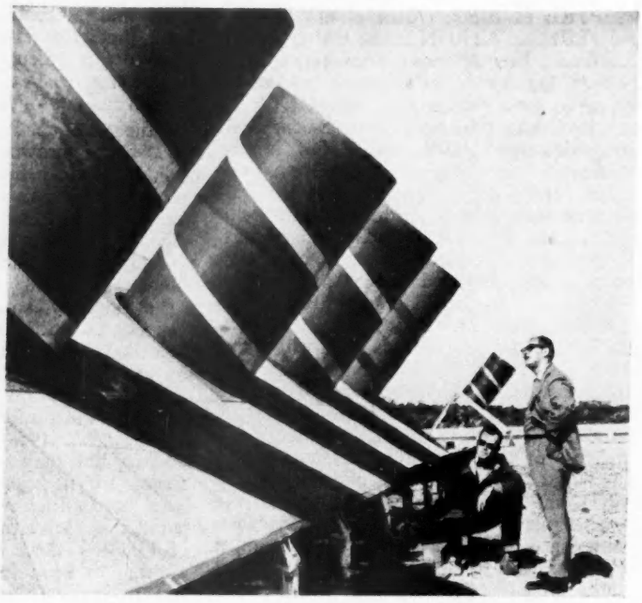
It is interesting to recall that the 2-6-0 "Mogul" type first appeared in America as early as 1850, and during the next ten years several examples were built. Following upon the invention of the Bissel truck, however, in 1863, the type was built more continuously and somewhat rapidly up till 1910–11, and most major American roads had the type in service. This wheel arrangement also found favour on many logging roads, and industrial plants, particularly in the 1870s–90s. It was designed primarily as a freight type, but was soon used as an all-round general-purpose engine, and as far as is known no examples appeared with driving wheels over 63in in diameter. Several roads often used it in passenger service, where the speed required was not too high. Some of the early examples when first built with extended wagon-top boilers and 63in drivers presented a most handsome appearance. Between 1860 and 1911 upwards of 11,000 examples were outshopped by most of the American makers for various railroads, including, of course, the specimens which ran on the Midland and Great Northern railways in this country some sixty years ago. On the introduction of the type the name "Mogul" was used to indicate by the makers an engine having a greater power output.

Wood burner engine, built in 1875. Now at Nevada State Museum, Carson City

The "Explorers"

By Dr. WERNHER VON BRAUN

The scientific earth satellites of the "Explorer" series and their launching vehicles formed the subject of a paper by Wernher von Braun at the ninth annual congress of the International Astronautical Federation, Amsterdam, last month. Dr. von Braun is director of the development operations division of the Army Ballistic Missile Agency, Alabama. Abstracts from the paper are reproduced here. The accompanying illustration shows the antenna system of the "microlock" receiving station at Cape Canaveral which tracked the initial phase of the "Explorer's" flight.



LET me first talk about the carrier rockets for our "Explorer" satellites. We call these carrier rockets "Jupiter C," because we have used these rockets in support of the development of a bigger rocket called the "Jupiter." The "Jupiter C" rocket consists of a modified "Redstone" rocket serving as first stage and a three-stage cluster of solid propellant rockets placed in a spinning tub which was mounted in the nose of the first stage. The entire "Jupiter C" thus has four stages.

The standard "Redstone" missile operates with a thrust of 75,000 lb and burns alcohol with liquid oxygen as the oxidising element. For the "Explorer" missions we enlarged the first-stage propellant tanks and selected another fuel, known as "Hydyne," to replace alcohol. "Hydyne" is a development of the Rocketdyne Division of North American Aviation Company, our power plant contractor. It yields from 10 to 15 per cent more specific impulse than does alcohol and can be used in an engine designed for alcohol and liquid oxygen without major modification. We actually increased burning time as well as thrust, boosting the latter to 83,000 lb or 8000 lb above the usual "Redstone" thrust.

The total weight of the high-speed clusters in the nose of the "Jupiter C" is substantially less than the payload weight of the "Redstone" missile. As a result, we could employ longer tanks for the satellite missions and fill these with some extra propellants for the first stage.

The instrument compartment sits atop the tank section and is separated from the latter after first-stage power cut-off. It accommodates the guidance and control equipment for the first-stage flight phase and a spatial attitude control system for horizontal alignment of the separated nose section with the spinning tub when it passes through the apex of its trajectory. The objective is to aim and fire the high-speed clusters prior to apex so that at injection the satellite would be travelling in exactly horizontal direction.

Firing Procedure for the "Jupiter C"

The missile takes off vertically under its thrust of 83,000 lb. During the 155 seconds' burning time of the first stage, it is tilted into a trajectory which is approximately 40 deg. inclined to the horizon at cut-off. A few seconds after cut-off, the booster—the combined tank and engine section of the first stage—is separated from the instrument compartment by igniting six explosive bolts which secure the compartment to the front end of the tank section of the first stage. Wrapped around these bolts are six coil springs which have been preloaded during the assembly procedure. At the moment the tiny powder charges destroy the bolts, the springs exert a gentle push on the instrument compartment and separate it cleanly from the booster. The velocity increment imparted to the instrument compartment by sudden expansion of the coil springs is in the order of 2·6ft per second.

We did not apply a refined cut-off for the first stage of "Explorer I." Instead we used the so-called depletion technique. This means simply that shortly before the expected burn-out time we energised two contacts. These contacts sensed the pressure in the fuel and the liquid oxygen pump discharge lines. Whichever of these two pressures dropped to zero first triggered a relay which, in turn, closed both propellant main valves controlling the flow into the combustion chamber.

Cut-off occurred after 157 seconds in "Explorer I," two seconds later than expected. Simultaneously a timer was triggered which activated the separation mechanism five seconds later. This prevented the run-up of the booster into the instrument compartment as a result of gradual thrust decay and permitted the thrust to decay completely down to zero before actual separation occurred.

From the point of separation, the two portions of the missile coasted through a vacuum trajectory until approximately 404 seconds from take-off. The apex was nearly attained at this time. During the free coasting period, between 157 and 404 seconds, the spatial attitude control system aligned the instrument compartment into an exactly horizontal position with respect to the earth's surface.

Attitude Control of Instrument Compartment

The same gyroscopes which had controlled the missile up to the cut-off point by means of jet vanes now (after separation) would control a system of compressed air nozzles which were mounted in the tail of the instrument compartment. The reaction thrust of these air nozzles tilted the entire nose section, complete with the spinning cluster of high-speed rockets, into the horizontal direction. The tilt actually occurred substantially faster than the tilt of the trajectory itself. We turned the nose section into the horizontal position relatively fast in order to give the residual errors sufficient time to decay. Thus, we obtained the highest possible degree of accuracy in the horizontal alignment by the time apex was finally reached.

Due to our relatively crude cut-off technique, based only on propellant depletion, it was impossible to predict exactly the time at which the apex would be attained prior to take-off. It was for the same reason impossible to determine exactly and in advance the horizontal distance the missile would have traversed between take-off point and apex. Because of the curvature of the earth and because the high-speed rocket launcher must be in exactly horizontal position over the local horizon, it was necessary to introduce some auxiliary tracking means to furnish additional data during the flight. Only by catching the moment of apex and by accurate alignment of the spinning tub would it be possible to ignite the high-speed stages in the right direction necessary to obtain orbital flight.

Three independent methods were employed to determine the instant of apex as precisely as possible. First, the missile was tracked by radar. The radar plot was used to predict the instant and point in space at which apex would be reached. Secondly, we had an accelerometer in the missile which, by means of telemetry, relayed to the ground the velocity build-up of the first stage. Cut-off velocity was then fed into a simple ground computer which predicted the instant of apex transit. Thirdly, standard Doppler tracking network furnished the same information.

The results obtained with these three independent apex prediction methods were introduced into a small calculator which enabled us to evaluate the quality of the three inputs. For example, if one prediction was based upon readings of poor quality, it could be disregarded or its value in determining the average would be reduced to about 20 per cent of the weight of the other methods. We could thus determine a rather reliable average of the apex predictions. The average was then employed to set a timing device which despatched a radio signal to the missile. It was this signal which fired the second stage. All this had to be accomp-

lished in the four-minute interval between cut-off and apex, of course.

We did not want to fire the second stage exactly at apex but slightly prior to this instant. The second, third and fourth stage had burning times of about five seconds each and several seconds elapsed between firing one stage and burn-out of the previous stage. Total elapsed time between firing the second stage and fourth stage cut-off was about twenty-four seconds. Firing of the second stage, therefore, had to occur prior to the predicted apex point. With this lead time the vertical velocity component of the high-speed cluster would be exactly zero at fourth stage cut-off.

The fourth stage, which orbits, consists of a single 6in solid rocket loaded with high energy propellant. A black-and-white striped unit on top of it is the instrumented satellite itself. The entire " Explorer " unit, that is, the empty shell plus the instrumented satellite, weighed 30·8 lb. The forward portion alone weighed 18·8 lb and the empty shell weighed 12 lb. The " Explorer " fourth stage assembly is 80in long and 6in in diameter. Similar rockets but with a slightly different propellant were used in the second and third stages. The second stage consisted of a ring of eleven of them. Inserted into this ring was the third stage consisting of three rockets. The single rocket making up the fourth stage sat atop the third stage.

The perigee altitude of 225 miles and apogee of 1594 miles corresponds to a period of revolution of 114·78 minutes. From post-launch tracking data, we learned that the angle under which the fourth stage entered orbit was, in respect of the local horizon, as little as 0·81 deg. off, which we thought was a remarkable accuracy in view of the many factors contributing to this error. However " Explorer I " would still have orbited had the error been as high as 4 deg. Thus a comfortable safety margin was available so far as accuracy requirements for apex attitude alignment were concerned.

Instrumentation

The satellite carried two transmitters. The low-powered transmitter in the nose is the same kind as the high-powered one located further aft, but it operates on one-sixth of the power level, radiating only 10mW instead of 60mW. It is fed by the same type mercury batteries but since they have about the same capacity in terms of ampere hours as those connected to the high-powered transmitter, they were expected to furnish about six times more lifetime : the high-powered transmitter had an expected lifetime of two weeks.

The first task of both transmitters was to provide signals for the tracking of the " Explorer " ; to prove, that is, that the satellite was in orbit. The high-powered transmitter could be received with any customary v.h.f. receiver but the low-powered one required more sophisticated, narrow band-width receiving equipment. Specifically, the latter could be received only by the " microlock " ground stations developed by the Jet Propulsion Laboratory for the Army and by the " minitrack " network established by the Navy, consisting of a long string of stations stretching from North to South approximately along the 65 longitude west of Greenwich. The stations provide a line across the North and South American continents which must be passed by any object orbiting at any moderate inclination to the equatorial plane. The "minitrack" network will receive any satellite transmission, provided it employs the right frequency, once per orbit and record the time of passing.

The transmitters also telemeter to the ground scientific information collected by the satellite. The telemetered data from " Explorer I " consisted of measurements of temperature, micrometeorites, and cosmic rays in space. Three temperature gauges were carried in the nose and the cylindrical portion of the outer shell to determine outer skin temperatures, and one inside the instrument compartment, behind the high-powered transmitter, to measure the temperature of the heat-insulated instrument package as compared to the outer skin.

For its second test objective " Explorer I " carried several instruments designed to determine the abundancy of micrometeorites in space and to determine how they, or tinier particles, commonly referred to as cosmic dust, affect the satellite's surface. Three different instruments were employed. One was a microphone amplifier mounted in the satellite's hull. This would register the impact of a micrometeorite and amplify it. A scale-of-two circuit was used to switch the frequency of a sub-carrier oscillator. Meteorite impact was observed through frequency changes. Dr. Bohn of the Research Institute of Temple University in Philadelphia developed this piece of equipment.

In addition to the microphone there was a micrometeorite erosion gauge, consisting of two instruments in one. A portion of it consisted of eleven wires of extremely brittle metal which were embedded in an insulating surface. A voltage was applied to the eleven wires in parallel. Each time a micrometeorite struck and broke a wire, the total number of wires connecting the plus and minus busbar would be reduced from eleven to ten, or ten to nine, or nine to eight, and so the resistance would increase in distinct steps. This change in resistance would be indicated on a sub-carrier oscillator. Two wires were put out of commission on the first orbit of " Explorer I." We believe now that they went out during the vehicle's ascent through the atmosphere. Apparently the density of micrometeorites in outer space, at least outside of recurrent meteor swarms, is not as high as anticipated. The erosion gauge was prepared by Dr. M. Dubin of the Air Force Cambridge Research Centre. Final results of the micrometeorite tests will be issued by the Air Force Research Centre while Iowa State University will publish the results of cosmic ray measurements.

Cosmic Radiation

The third, and most important, experiment was performed by a Geiger counter, compactly packaged and assembled, which was developed by the State University of Iowa under Dr. James Van Allen. The purpose of this counter was to determine the intensity of cosmic primary radiation in outer space. The total weight of the instrumentation performing all three experiments in " Explorer I " was a mere 10·83 lb. From this inauspicious springboard there developed a major scientific discovery in physics, which was completely confirmed by the data collected with " Explorer III."

The first analysis of the results of Dr. Van Allen's cosmic ray probe proved fascinating and bewildering. " Explorer I's " radiation counts ran about thirty to forty per second some 200 to 300 miles above Southern California, as had been predicted. But the count climbed to more than 35,000 per second at the highest altitudes of both " Explorer I " and " Explorer III " when they were over South America and adjoining waters. This figure could possibly have been higher, because the instruments were completely overwhelmed at this extremely high and unexpected cosmic ray count.

Due to existing weight limitations the " Explorer I " counter could report only the number of impinging cosmic primary particles within the counter's sensitivity level. Unable to differentiate between the energy levels, it could not catalogue the total into heavier and lighter, or faster and slower cosmic particles. Moreover, with " Explorer I " we could record impingements only while the transmitter was in direct line of sight with at least one receiving ground station. We lost most of the telemetered information over areas where no receiving stations existed.

For more complete data gathering " Explorer III " carried a tape recorder which stored information acquired throughout the entire orbit and reported it, on command, when the satellite passed over a suitably equipped receiving station. It is a small magnetic tape recorder driven by a spring with a little battery-powered electric step motor which wound the spring continuously. A coded radio signal flashed to the satellite from the ground triggered a relay which unlatched the tape reel so that the spring drove the tape through the playback pickup within about five seconds. Within this period the transmitter, turned on by the same relay, played back to the ground whatever had been recorded on tape during the last orbit. To conserve power the transmitter was turned off after relaying the tape information. Since the little step relay continued winding the spring, the unit would again play back two hours or so later, after the next orbit. Each time the tape was played back, it was simultaneously cleaned for new information. Consequently the process of recording, storing and playback continued as long as the battery lasted. The system functioned perfectly.

The presence of an exceptionally high particle impingement rate was indirectly concluded from a rather sudden, and complete absence of telemetered pulses while near the apogee of the orbits. The instruments were carried out to altitudes in excess of 1100km. As it was inconceivable that there existed an area void of any cosmic ray count, this temporary absence of any pulses was interpreted as signifying a blanketing of the Geiger tube by a very dense radiation field. Calibration of the equipment in the laboratory indicated that such complete blanketing of the Geiger tube would require a counting rate of at least 35,000 impacts per second. It was further concluded that only a small portion of these rays could be of high energy classification, identified as cosmic rays, and that most of the count was made up of a little-known low-energy type, presumably either electrons or protons. There was no way to determine their source, whether the particles came from the sun, or from interstellar space.

The instrumentation in " Explorers IV " and " V " was designed to investigate this exciting radiation phenomenon more closely. To permit the maximum exploitation of our relatively small carrier, the micrometeorite and temperature experiments carried in " Explorers I " and " III " were eliminated. Even the tape recorder in " Explorer III," that permitted the storage of information gathered throughout orbit, for release *in toto* at a single receiving station, was sacrificed. Weight reductions in the upper two stages of the " Jupiter C " launching vehicle, combined with the use of more powerful propellants, permitted an addition of 7 lb of instrumentation in " Explorer IV " and " Explorer V," bringing the total weight of the satellite instrumentation up to 18·26 lb.

All the instrumentation, devoted to this one experiment, was designed to break down the radiation count into levels of intensity. Four separate radiation counters were carried instead of the single counters in " Explorers I " and " III." Two Geiger-Müller tubes, similar to the one each flown in the earlier satellites, were complemented by two scintillation counters. One each of the tubes and scintillators was shielded with lead to eliminate data below certain energy levels. The shielded counters would respond only to high-energy particles, while the unshielded counters were expected to detect everything. Also, the unshielded scintillation counter had special pickups which could further differentiate between energy levels.

The new instruments in " Explorers IV " and " V " were capable of detecting radiation accurately up to the range of 60,000 particles per square centimetre per second, which is several thousand times greater than the capacity of the equipment used in " Explorers I " and " III." The satellite instrumentation for " Explorers IV " and " V " was designed, assembled and tested under the supervision of Mr. Josef Boehm of the Army Ballistic Missile Agency. Dr. Van Allen's institute again furnished the counters and, for telemetry, we used Jet Propulsion Laboratory's proven " microlock " system.

The highly elliptical orbits bands planned for " Explorers IV " and " V " were calculated to cover most of the earth's surface. Their orbital inclination with respect to the equator was 50 deg. compared to the 35 deg. of " Explorers I " and " III." When I was preparing this paper, " Explorer IV " was still sitting on its launching pad, and " Explorer V " was still in the checkout hangar.

Firing Operations

The jet vanes for the " Jupiter C " caused us some concern for a while. Most of the testing of the rocket engine with the " Hydyne " fuel had been conducted by Rocketdyne at its own California facility, while the testing of the jet vanes to determine compatibility was conducted by our Army Agency in Huntsville, Alabama. We were concerned about the combined effect of extended burning time and higher exhaust velocity upon the vanes, since erosion might have reduced our control below the minimum level. It developed that the new fuel eroded the standard jet vanes far less than alcohol. The extended burning time achieved by using " Hydyne " also required an enlargement of the hydrogen peroxide tank for the engine, simply to keep the turbine running for that extra period. This modification was provided by Rocketdyne.

Numerous cables and tubes connect the instrument compartment and booster. All have quick-disconnect couplings so that at separation the plugs separate and the lines part quickly and easily. For a research project such as " Explorer I " with its relatively simple guidance system, access doors were eliminated and the entire cover had to be lifted to service the instrument compartment.

On the cylindrical part of the instrument compartment are a number of antennæ. One is a telemetering antenna ; two are part of the Doppler antenna system. On the other side is a radio command antenna.

In the Cape Canaveral flight preparation hangar the instrument compartment was bolted to a rocking table placed at the bottom of a 10ft pit. The instrument compartment could be rotated and rocked back and forth in two planes because the table is gimbal-suspended and driven by three electric motors. The gyros were run inside the compartment ; thus, any error angles developing between the stable gyro reference and the rocking instrument compartment are picked up by potentiometers. Depending on whether the test is concerned with the control phase of the powered first-stage flight, or to check the function of the spatial attitude control nozzles operative after separation, a direct response of the jet vanes or the air nozzles occurs. This permits determination, for example, of the correct flow rate in the compressed air nozzles, or points out a sticky control needle, or a wrong polarity. The entire control system in all its functions was thus tested.

Four double nozzle units are attached to the instrument compartment, two for pitch and two for yaw. The two nozzles on each unit yield a thrust, at full flow, toward right or left of approximately 5 lb. Air flow is controlled by a small electric motor driving a sprocket wheel ; cogs of the wheel engage the teeth of a push-pull needle. As the needle, driven by the motor, moves to right or left, more or less air is admitted to either nozzle. Smooth movements of the needle provide a " proportional control " system in contrast to the " bang-bang " type of control employed in the standard " Redstone " missile. The refinement was necessary for accuracy reasons. The accuracy observed in rocking tests is $^1/_{10}$ deg.

One of the more difficult problems encountered in the development of " Explorer " was to make this proportional attitude control system absolutely linear under vacuum conditions. With a vacuum outside, supersonic flow occurs within the nozzle even at very small rates of air flow. This tended to cause an " s "-shaped response curve which was difficult to straighten out. After some effort, very precise control was obtained, however. Roll control was fed to all four electromotors in the form of differential signals.

Before the launcher could be mounted atop the elongated booster, it had to be spin-tested for static and dynamic balancing. A special rig was built which consists of a cage suspended on four rods inside an outer structure. The inner cage surrounds the spin launcher. As the latter is spun up, any unbalances are detected, located and remedied with the aid of a stroboscope.

Electric motors drive the cluster up to speed ; that is, the entire launcher tub with the rocket clusters inside. If the tub is not completely balanced, the inner cage will vibrate within the outer frame. The amplitude and pattern of this vibration is measured with a stroboscopic method which permits exact determination of the locations where balance weights must be added. The technique is widely used in industry to balance dynamically such things as gyroscopes and flywheels. The spin-up facility was designed and developed by the Aerophysics Development Corporation.

Rockets for the second and third stages are hidden within the tub, while the fourth stage with the satellite payload appears at the top. The tub is an empty aluminium cylinder. Inside are two rows of grooved bosses, one row at the top and the other at the bottom of the tub. The grooves provide support and guidance for lugs attached to the second stage. Inside the second stage are grooves which hold the lugs of the third stage. The lug-and-groove type of holding technique is the exact equivalent of a zero rocket launcher; whenever the second stage has travelled forward as little as $\frac{1}{2}$in within the tub it is completely free and could make lateral moves of several inches without collision with the tub wall. The same is true of third-stage clearance *vis-à-vis* the second stage.

The fourth stage, however, is mounted atop the third stage in a conical holder attached to the forward end of the third stage. The satellite payload is mounted at the top of the fourth stage. Final spin-up and balancing tests were conducted with the live clusters at Cape Canaveral by the Jet Propulsion Laboratory which provided them.

A conical non-rotating support carries the two heavy ball bearings of the spin-up launcher. Underneath it are the two electric motors which spin the tub. The drive mechanism is quite simple. It consists of two sprocket rubber belts which transmit power from the electric motors to the tub.

Cluster Run-up

Prior to launching, the tub is rotating at 550 r.p.m. The missile takes off when this speed has been attained. About seventy seconds after take-off, a governor controlled by tape progammer inside the missile changes the regulator setting gradually up to 650 r.p.m. At 115 seconds after take-off, it rises to 750 r.p.m. Thus, while the first-stage flight is in progress, the rate of spin slowly accelerates.

This procedure was selected to avoid resonance between the spin frequency of the cluster and the bending frequency of the booster. This bending frequency changes as propellants are consumed. The revolutions per minute must be kept down to 550 so long as the tanks are full and the bending frequency is correspondingly low. Only after the booster has consumed a substantial volume of propellants can the spin frequency be increased. The increase is about proportional to the increased bending frequency. At no time in flight is a critical frequency experienced.

About twenty seconds before cut-off, the maximum spin rate of 750 r.p.m. has been reached. There is no change in it during the free coasting climb to apex. Because the 750 r.p.m. rate is controlled by a governor, there is sometimes a slightly greater and sometimes a slightly smaller load on the electric motors. These varying loads exert a reaction torque on the instrument compartment attached to the spin launcher and, in free coasting flight, the torque must be compensated by the compressed air nozzles of the spatial attitude control system. Otherwise the instrument compartment could acquire a spin under influence of this reaction with resulting gimbal lock and spilling of the gyroscopes. The thrust of the spatial attitude compressed air nozzles had to be sufficient to cope with these governor reaction torques.

One more consideration in this area should be mentioned. The presence of the spinning cluster in the nose of the instrument compartment means that the attitude control system must tilt a non-rotating body with a heavy gyro mounted in its nose. As it is tilted, the precession forces caused by this gyro must be considered. In practice, the unavoidable precession forces were put to good use ; in order to tilt the unit in the pitch direction air was blown out of nozzles pointing in the yaw direction. Thus the precession force of the spinning cluster was employed to tilt it in the pitch direction. The technique and the proper control gain settings had been worked out by analogue simulation previously.

In the so-called steam generator the hydrogen peroxide is catalytically decomposed to produce an oxygen-rich steam. This steam drives the turbine which, in turn, drives the two centrifugal propellant pumps which feed the fuel and liquid oxygen into the combustion chamber of the rocket engine.

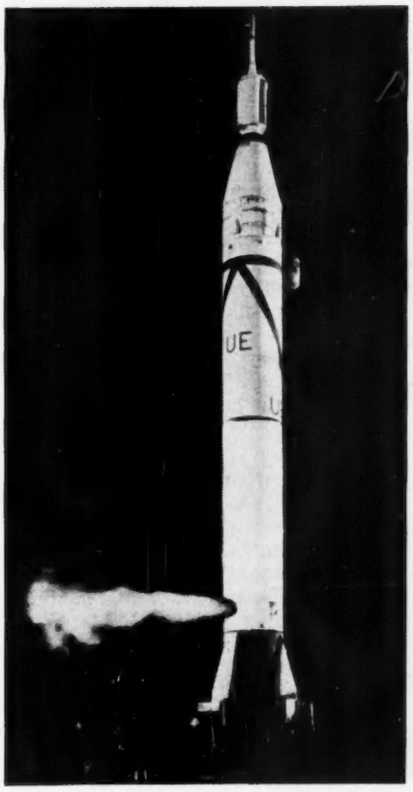
The launching table is a simple device,

made of steel, with four legs through which the rocket jet passes. A conical deflector underneath spreads the jet in a horizontal direction. The service structure is mounted on two sets of wheels which run on wide-gauge rails. The structure is rolled back 300ft for the launching.

Launching

Inside the blockhouse are the cluster speed control panel, the rocket engine panel with its ring-shaped safety key, the electrical power supply and network monitoring panel, and the panel for the first stage guidance and control system. From the instruments the operator can see whether all four rudders are in zero position and whether the gyroscopes are properly levelled. Finally there is a radio equipment panel. A rack of sequencing recorders is also provided to permit continuous monitoring of such items as hydrogen peroxide temperature, functioning of the instrument compartment cooler, and transmission of the microlock transmitters in the satellite. The test co-ordinator calls out the consecutive steps listed in the countdown table, receives compliance reports, and synchronises the missile preparation with the range operation including tracking stations and photographic groups.

In the accompanying illustration the structure has been withdrawn and " Explorer I "



The service structure has been withdrawn and " Explorer I " awaits launching. The object protruding (upper right) is the preflight instrument compartment cooler, a dry ice container which is magnetically jettisoned from the missile just before take-off

awaits launching. Oxygen vapour issues from the " lox " vent valve, which will be closed prior to tank pressurisation which begins immediately before firing. Protruding on the upper right is the preflight instrument compartment cooler. It is a dry ice container, combined with fan and thermostat inside the instrument compartment. When, because of heat dissipation of electrical equipment, the compartment temperature becomes too high, the thermostat cuts in the fan and the fan circulates air through the dry ice until the temperature is reduced enough to stop the fan. Immediately prior to take-off, the preflight cooler is disconnected magnetically from the missile and falls to the ground. By the time it strikes earth, the missile has left the launcher.

Simultaneously with disconnection of the preflight cooler, the entire cable connection between missile and ground is severed. Only a few electrical contacts remain in the tail, such as a take-off contact signal and an emergency cut-off connection in case of inadequate thrust build-up. The spin-up top is clearly visible. Spin commences at thirteen minutes prior to launching.

Insulating cylinders made of a plastic form the bases of the antenna system of the " microlock " receiving station at Canaveral which tracked the initial flight phase of the " Explorers." Around them a helix of sheet metal is wound so that it becomes a helical antenna with moderate directional pattern. A wire base provides a reflection shield. Phase comparison between the two antennæ separated by a given distance indicated the path of the missile-borne transmitter through space. More elaborate arrays of such antennæ, suitable for interferometric determination of flight path, were used at other stations in Nigeria, Singapore and California. There was also a simpler station at Antigua in the Lesser Antilles, 1300 nautical miles downrange from Canaveral. The Navy's " minitrack " network provided the North–South picket line previously mentioned which received on the same frequency as " microlock," about 108 Mc/s.

As long as the first stage was firing during take-off of " Explorer I " the blockhouse operators could watch recorders of an electronic display system which indicated whether or not the missile was following the predicted path. After first-stage cut-off and separation of the nose section, the next important operation was the prediction of the instant when apex would be reached and the high-speed stages had to be fired. Concurrently the attitude of the instrument compartment had to be continuously monitored by telemetry to make sure that during the free coasting period the attitude control system did not fail.

Presently the signal had been given for second-stage firing and a few minutes later Antigua reported that both transmitters of " Explorer I " had been clearly heard as the satellite passed that point. The time elapsed between firing the second stage and the passage over Antigua was a pretty good indication of whether the final speed of the fourth stage would be sufficient for orbital velocity. As a result of the measured travel time, it was concluded that " Explorer I " must have settled in a 106-minute orbit. It later on turned out that the actual period of revolution was a little over 114 minutes, and those eight minutes' difference, during which we waited in vain for the signals to be picked up by our receiver station in California, indicating that " Explorer I " had successfully circled the globe, were the longest eight minutes of my life !

Orbits and Temperatures

The satellite was covered with dark and white longitudinal stripes to prevent extremes of heat and cold under the effect of solar radiation or lack of it. Imagine that the orbit were going around the earth in such fashion that the axis of the orbit pointed toward the sun. Then the satellite will always be in sunlight. Now consider the case where the axis of orbit points 90 deg. away from the sun. Then the satellite will spend about one-half of each revolution in sunlight and the other half in earth's shadow. If the orbit is very high, of course, it will be substantially more than 50 per cent in sunlight because the diameter of earth's shadow would be substantially less than orbital diameter. At any angles between zero and 90 deg. between axis or orbit, and direction toward the sun, different times of exposure to sunlight will be found. But since the earth rotates about its axis and along with the earth's surface goes the firing site, it is clear that these exposure times depend upon the hour of firing. Moreover, as the earth revolves around the sun and therefore the direction toward the sun prescribes a full 360 deg. movement throughout the year, exposure times to sunlight must also vary as a function of the time of year.

If we launch a satellite during the month of May from Florida between 2 p.m. and 7 p.m., in the afternoon (1400 hours to 1900 hours), during the first sixty days of orbiting there would exist a period wherein for a considerable number of consecutive revolutions, the satellite would be in sunlight 100 per cent of the time. Even without additional heat stemming from electrical equipment, the satellite would become too hot. If we launched instead between 6 a.m. and 12 noon, the time of exposure to sunlight will be between 70 and 80 per cent, which is acceptable.

Temperature measurements were taken in " Explorer I " inside the body, right behind the high-powered transmitter. The predicted cyclic temperature changes are exceedingly small. They vary between 100 deg. and 120 deg. Fah., about the same temperature region experienced on a hot summer day in the Far West of the United States. The fact that the variation is so small is mainly due to the fact that the electronic equipment within the satellite is heat-insulated from the outer skin. The rather densely packed units have a certain amount of heat capacity and simply level off the peaks in variations of outer skin temperatures. The extent to which these peaks can thus be levelled depends solely upon the ratio between heat capacity of the instrumentation and the heat insulation between the latter and the skin.

" Explorer I," launched on January 31, 1958, is still up in its orbit, but its batteries are dead by now. " Explorer III," launched on March 26, 1958, completed approximately 1260 revolutions before its disappearance on June 28, 1958. Its eccentric orbit ranged between a perigee of 116·86 miles and an apogee of 1740·77 miles on the initial pass, and 107·2 miles and 650·2 miles, respectively, about two weeks before it vanished. The period of revolution dropped from 115·87 minutes initially to 96·885 minutes. The rate of decay measured at apogee was 11·36 miles daily between March 26 and April 11, 11·95 miles between April 11 and 25, 14·99 miles between April 25 and May 31, 14·16 miles from then until June 10, and 16·9 miles thereafter. We are still busy figuring out what this means in terms of atmospheric densities encountered at these altitudes. At first we had been a bit disappointed about the high eccentricity of " Explorer III' s" orbit, but this eccentricity soon proved to be a bonus, as it meant a greater spread between minimum and maximum altitude. For the survey of those newly-discovered radiation phenomena which I mentioned previously, this turned out to be extremely valuable.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

"THE SPIRIT OF ENGINEERING"

SIR,—Mr. Hugh Clausen's article, "Engineering Design," left me terribly impressed, but it gave the impression that the design engineer is the neglected man in England, but not in other parts of the world. It might be only a small consolation to your readers to learn that the same sad state of affairs exists in the United States as well, and in no lesser degree.

As a design engineer with thirty years of experience, and as former professor of a technical college in the U.S.A., I have realised that more and more the key man in engineering has been shoved in the background in favour of the so-called business administrator, the sales engineer, the production engineer, and the junior executive. The result becomes apparent in unsatisfactory structures, in the high percentage of failures, in excessive costs and in changes that are necessary during as well as after construction.

We notice everywhere the tendency to consider design, planning and careful study as secondary and sometimes as a complete waste of time, and as a result, the desire of the student to become a real designer is lessened because the financial reward and the glamour of the title "executive" induces him to follow the business career. After all, a swivel chair and a nice desk is much more comfortable than a draughting stool and a drawing-board.

Only after the Russians successfully launched the "Sputniks" did the U.S.A. come to the realisation that somewhere, somehow, something was wrong. Immediately the cry went up that we have an acute shortage of engineers and that we must produce more engineers as fast as possible. This at a time when hardly any firm considers the application of an engineer of forty years of age and over, and when engineers over sixty or sixty-five years of age were sent to retirement, regardless of physical condition. The proposed remedy of the politicians is typically American ; we must increase our production of engineers in our universities and colleges to keep up with the Russians. This we do by granting more scholarships and by luring the bright young men to take up engineering and physics. The National Society of Professional Engineers rightfully denied that there was a shortage of engineers, and pointed out that quite a high percentage of engineering graduates have never done any engineering and are employed as administrators, expediters, purchasing agents, co-ordinators, assistants of all kinds, sales engineers ; in other words, are employed in non-technical fields, far removed from actual planning and design. We have only one shortage of one kind of engineers, and that is high quality and well-trained and experienced design engineers, who can combine theory with judgment, who know materials and construction, and who "believe in thinking before and not after."

True, no structure is better than its design, and no engineering firm is better than its design department, but lately too much emphasis is given to production and speed of construction, very little understanding and hardly any consideration is placed on quality of design. In the desire to speed up the job, "to get into orbit" before the next competitor, we neglect the importance of sufficient study, of verifying and checking and, consequently, we have failures.

There is no substitute for hard work at school, and engineering courses are much more difficult than the liberal courses, and if we think that certain nations are superior in quality of engineering design, such as the Swiss, Germans and Russians, we find the answer in the training programme of their high schools and universities as well as in the financial and social standing of the engineers in these countries compared to the conditions in ours. As long as the college professor is working for a salary way below that of the man in industry, few will be interested in such a career. The majority of high school professors are paid less than a skilled worker, and in many cases the football coach is the best paid man on the faculty. That is certainly not true in other countries.

We can only compete with other nations if we follow their pattern of developing engineers and if we make it worthwhile and glamorous enough to be a design engineer ; if not, we shall produce a great number of mediocre, so-called engineers, who hardly deserve to be called engineers.

As Mr. H. Clausen pointed out, it is high time that management starts to realise that there will never be a substitute for good design, and that quality of design cannot be realised on a production line. The sooner this is realised by those who govern the destiny of engineering works, the better. Time is running short.

G. E. SCHUMANN,
Consulting Engineer.

Oakland, California.
August 26, 1958.

SIR,—There are two further points concerning the letters published in your issue dated August 22, 1958, dealing with the above subject, and with Mr. Clausen's lecture to the Institution of Engineering Designers, to which I should appreciate an opportunity to refer.

First, to apologise to Mr. Clausen and to your readers for the misquotation he referred to. I am sure he will understand that I was searching for a comprehensive form of words which would summarise the meaning he had given to "the philosophy of craftsmanship."

Dictionary definitions and modern interpretations of engineering terms, including the term "technology," leave much to be desired in scientifically presenting their meanings to scholars in general, and to students in particular.

Here is a definition of the fundamental meaning of the term, "The Spirit of Engineering," which I find helpful to me ; it embraces the work of engineers in all categories and I put it forward for consideration.

"The art of bringing ideas to fulfilment." One of the dictionary definitions of "idea," which seems to me to be fundamentally sound is : "An image in mind." I believe that, starting from "idea," and "image in mind," the subsequent stages which are passed through towards the fulfilment of the idea are controlled by fundamental laws operating within a four-dimensional calculus. I suggest that engineers, artists, and all men of goodwill should search to establish these laws and set up a suitable text-book of standards. Mr. Clausen has, in his lecture, named the four-dimensional calculus within which such fundamental laws operate, i.e. "The science, the art, the industry, the finance or commerce."

Secondly, I should like to thank Mr. Garrett for his brilliant synthesis of relationship between the æsthetic and technological functions of engineering, by the comparison he made between Waterloo bridge and Charing Cross railway bridge. This comparison is a very important aid to the understanding of the form order of four-dimensional thinking.

"Science is knowledge reduced to law and embodied in system." A scientifically-minded man starts to deal with an abstract idea—"an image in mind," but as soon as he gets out his drawing-board and lifts his pencil he enters the realm of engineering ; call it technology, engineering science, the spirit of engineering, or any other term representing the act of "reducing knowledge to law and embodying it in system," and he thereby gains a reverence for, and an appreciation of, creative ideas and fundamental law which he is humbly endeavouring to bring forth.

The deliberations of the British Association for the Advancement of Science, which are being reported this week, illustrate the great need for a further effort to be made to break through the mists of complacent satisfaction with past achievements and to start a search for the fundamental principles or root notions which Albert Garrett has so succinctly described as "the problems of communication between science, engineering, and the arts."

It is a further turn along the road, the road toward a better appreciation of the nature of absolute truth.

Do your readers agree that a case for more research has been made ? If so, no doubt, ways and means whereby such research could be undertaken will be suggested.

The findings of such research will enable mankind to move forward more harmoniously and with greater confidence into the "Atomic Age" and on towards a better conception of the purposes of life.

CHARLES OSBORNE

Torquay,
August 29, 1958

Book Reviews

Gas Dynamics. By A. B. CAMBEL and B. H. JENNINGS. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 85s. 6d.

THE term " Gas Dynamics " has been introduced to describe gas flow when flowing fluid cannot accurately be treated as incompressible and of constant density, as it was in classical " aerodynamics," " fluid flow " and " hydraulics." These large changes of density arise either from large changes in absolute pressure arising because the Mach number is not negligibly small or from high velocity combustion of the recirculation stabilised type. Thus, the problems of gas dynamics have become of great importance in the last twenty years as a result of : (1) the external flow in the propulsion of aircraft and rockets at Mach numbers equal to or greater than unity, and (2) the internal flow in combustion chambers where the Mach number is usually appreciably less than unity but the velocities are nevertheless very large compared to the laminar flame propagation velocity.

This book can be regarded as a logical development of two lines of thought, each with its own experimental verification, which eventually merge. On the one hand, there are the thermodynamics of expanding gases and classical aerodynamics combining to produce aerothermodynamics with shock waves, supersonic flow, nozzle flow and multi-dimensional flow as main subjects ; on the other there are the thermodynamics of physical chemistry, classical combustion theory (reaction mechanism, flame propagation, ignition and quenching) combining with high-speed recirculation flow phenomena to produce aerothermochemistry. It is undoubtedly extremely useful to have a clearly written book which does state the basic theory and equations in these two lines of thought, although we would prefer to see certain parts treated much more fully than they are here. Thus, in the chapter on multi-dimensional flow, the equations are not applied to the truly multi-dimensional problems such as a jet penetrating across another flow at right angles. This is a flow problem that has great bearing on the mixing of dilution air in a gas turbine combustion chamber as well as the elimination of smoke in a locomotive firebox, whereas the chapter is really confined to the flow which is still a close approximation to one dimensional such as a converging or diverging nozzle. It is probably legitimate that another flow problem of great interest is excluded from the treatment, because buoyancy forces due to density differences only affect the flow patterns to a very limited extent when the velocities are very high.

In the final chapter on aerothermochemistry, the theories that have been very thoroughly worked out for the blow off and combustion efficiency of the recirculation stabilised flame behind a baffle or gutter, for example, by Spalding, are treated very inadequately, and even on the experimental side more results are given for the much less important case of the opposing jet flame holder. This seems a great pity, as a really good clear treatment of recirculation stabilisation theory is the very essence of aerothermochemistry, which is surely the theory of aerodynamically stabilised flames in contradistinction to flames stabilised by the laminar or turbulent upstream diffusion of heat or reacting radicals.

It is clearly very valuable to have in such a book chapters on dimensional analysis and similitude and on experimental techniques and measurements, and these subjects are well covered. A point of minor disagreement in the former chapter is that we regard the derivation of the dimensionless numbers from the fundamental differential equation as a much more informative method than their derivation from dimensional analysis, whereas here it is rather briefly dismissed as " descriptive dimensional analysis." Experimental techniques are very profitably brought together in one book, the treatment ranging from the use of rotten wood for smoke production in flow visualisation to the mathematical theory of the Schlieren technique. Temperature measurement in high velocity non-burning streams is dealt with quite separately from flame temperature measurment, which is a legitimate separation from the point of view of the actual experimental techniques used, but it leads to a rather inadequate account of flame temperature measurement, as the suction pyrometer and the Schmidt and the Kurlbaum radiation methods are not mentioned.

The book follows the American practice of having illustrative problems listed at the end of each chapter and worked out examples where they are helpful to the text, within the body of the chapters. There is a very useful collection of tables at the end, especially a detailed table of the thermodynamic properties of air at low pressures (in the Rankine-Fahrenheit-B.Th.U. system of units which are favoured in America, whereas British gas turbine engineers usually favour the Kelvin-Centigrade-C.H.U. system), and tables of constant area flow of a perfect gas with $k=1\cdot4$ both frictionless with heat supply and frictional but adiabatic.

To summarise, the book can be strongly recommended as a reference book that brings together much theoretical and experimental work in this recently-defined field, but the choice of emphasis of certain parts of the field can be criticised.

Concrete Technology (Vol. I). By D. F. Orchard. Contractor's Record Limited, Lennox House, Norfolk Street, Strand, London, W.C.2. Price 45s.

IN this book, the first of two, Professor Orchard covers the properties of the constituent materials of various kinds of concrete. The book is admirably produced with many clear diagrams and tables. The majority of the written matter is, of course, not the result of the author's experiments. He is to be congratulated upon the very widespread source of material and the full list of references at the end of each chapter. These references will enable the reader to study in greater detail any points in the text which are summaries of technical papers.

The first chapter deals with various kinds of cement, in Europe and America, and in some seventy pages it covers the subject completely from the civil engineering point of view. A chapter on the effect of additives, this word being used in its widest sense, follows. Aggregates of all kinds are discussed in chapter three, followed by lightweight concrete. In this section the rather surprising statement is made, without a reference, that the denser the concrete is made the greater is its resistance to sound transmission. Chapter five devotes ninety pages to the difficult task of explaining how to design concrete mixes, with the aid of several worked examples. The chapter on properties of concrete is somewhat disappointing in its detail, probably because the author has not worked in the field and has to rely on the work of others.

This book is a compendium of knowledge rather than a series of paragraphs progressing from one to the other. In a work of this nature it is difficult to avoid commencing each paragraph or sentence with the definite article; in this respect the book improves with each chapter.

The Performance and Design of A.C. Commutator Motors. By E. OPENSHAW TAYLOR, B.Sc., A.C.G.I., D.I.C., M.I.E.E., M.Amer. I.E.E. Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 45s.

THIS book is intended as a companion to Clayton's *The Performance and Design of D.C. Machines* and Say's *The Performance and Design of A.C. Machines*, so that these three books from the same publisher should cover the whole range of rotating electrical machinery. The new book gains in importance with the gradual disappearance of direct current distribution and the consequent increasing demand for a.c. commutator motors for variable speed drives. Principles common to every kind of a.c. commutator motor are set out in the first part of the book. Subsequent chapters are concerned with commercially successful methods of obtaining variable speed, beginning with auxiliary commutator machines for regulating speed of induction motors. The major part of the book is then devoted to three-phase commutator motors—including the Schrage motor, the " Osnos " (no-lag) motor and the series motor—and to the various kinds of single-phase motors. There are two appendices, one on harmonic analysis and the other on the current locus in circuits containing resistance and reactance.

Reactors of the World. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 10s. 6d.

CUT-AWAY drawings of a dozen reactors are reproduced in this booklet, together with some of the leading data relating to them. The reactors included are : the British BEPO, DIMPLE, ZEUS, LIDO, DIDO, Calder Hall, Dounreay (fast), and Bradwell ; the Canadian NRX ; the American EBWR and CP5 ; and a Russian power reactor. Few readers will be deceived by the rather startling implication in one or two of the data sheets that the atomic number of uranium can be 238 and 235, while plutonium of atomic number 239 can also be produced. Printer's slips of this kind will no doubt be rectified in later impressions, and do not reduce the interest of the drawings. The latter appear on folding sheets about 17in by 11¾in, and usually include one or two human figures to lend them scale. The front cover has the words *First Series* under the rather comprehensive title, indicating that this booklet is the first of a number.

Books Received

Ensembles Mesurables et Probabilisables. By D. Dugue. Dunod, 92, Rue Bonaparte, Paris (6eme), France. Price Fr.850

Nichtlineare Mechanik. By Hans Kauderer. Springer-Verlag, Reichpietschufer 20, Berlin W 35, Germany. Price DM.64.50.

The Calculations of Deformations of Welded Metal Structures. By N. O. Okerblom. H.M. Stationery Office. Price 15s.

Richtlinien für die Aufbereitung von Kesselspeisewasser und Kuhlwasser. 5th Edition. Vulkan-Verlag, Dr. W. Classen, Essen, Germany. Price DM.46.

Theorie und Berechung der Stahlbrücken. By A. Hawranek and O. Steinhardt. Springer-Verlag, Reichpietschufer 20, Berlin W 35, Germany. Price DM.66.

The Analysis and Design of Steel Portal Frames. By J. G. Henderson and J. K. Henderson. The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey. Price 3s.

Vibration Waves in Concrete

By N. S. FARRAR, M.Sc. (Eng.)

In two previous articles on this subject Dr. J. M. Plowman described the results of vibration tests on the compaction of concrete, as measured in terms of the acceleration at various points throughout the mass of concrete being vibrated. Further work has been carried out with reference to table vibration by the author, in both the theoretical and the practical aspects of vibration as it affects concrete compaction.

CONTINUATION of the work described by Dr. J. M. Plowman in two articles in THE ENGINEER[1,2] is explained here. In addition to practical work, a theoretical approach to the manner in which the particles of a mass of concrete undergo excitation has been devised. This theory, relating to the decay of vibration waves as they pass through a mass of concrete being compacted, is based upon an impedance method of analysis developed for general vibratory systems by P. F. Chenea[3] in the United States. Essentially, it consists of breaking down the vibratory system into its constituent elements, viz. those of elasticity, viscosity, and inertia, and examining each in its effect upon the material under consideration. The material of fresh concrete is usually referred to as being visco-elastic, and the impedances of the constituent elements are defined as the ratio of an exciting force to the displacement which that force produces. This impedance can be computed for each element in terms of the complex variable, since the vibration is assumed to be one of simple harmonic motion. Introducing this concept into the vibration of an unconfined mass of concrete, we obtain a relationship between the displacement amplitudes at any two points, and hence between the acceleration amplitudes. An approximation to the theoretical decay of the vibration waves between any two points is as follows:—

$$A = A_0 \cdot \cosh Nx$$

where

A_0 = the acceleration amplitude at any given reference point, usually the origin of the vibration.
A = the acceleration amplitude at a point distant x from the point of A_0.
N = a constant, depending upon the concrete mix.

In the tests here described, the concrete mix used gave rise to a value of N equal to 0·06.

A method was also developed of determining the value of the constant N from a knowledge of the acceleration ratio between two points where there existed a phase difference of π radians. However, it was discovered in practice that the nature of the vibration waves was non-linear, whereupon this method lost its usefulness. It was possible to determine the value of N empirically, and this was done in preference to the earlier method.

From the theory of decay propounded above it can be shown mathematically that (i) the damping of the vibration waves is independent of the cross-sectional area; (ii) the damping is less for concrete of a higher density; (iii) the damping is greater for a more elastic concrete; (iv) the damping is greater for a more viscous concrete. These latter three factors would appear to be consistent with the behaviour of normal materials undergoing physical excitation, and the first conclusion can be assumed to be purely theoretical, since the presence and condition of any formwork has an undoubted effect upon the concrete vibration.

This theory was put to the test using the accelerometers described by Dr. Plowman.[2] In order to record measurements of acceleration at points simultaneously a double-beam oscilloscope was used with independent channels to any two of the several accelerometers used in the test. Using this double channel it was also possible to record simultaneous measurements of the relative phase angles of the vibration waves, and thus to determine the wave velocity and wavelength.

Tests were also performed using a large number of accelerometers distributed over a vertical area of concrete. These indicated the relative acceleration of points in that area, and thus provided a pattern of iso-acceleration contours for any given concrete section being compacted upon a vibrating table. These latter tests were the first to be performed and employed an experimental approach similar to that described in the preceding article. The concrete was mixed in a tilting drum mixer and placed in a stiff wooden mould of size 12in×36in×20in in height, with twenty accelerometers placed in a vertical plane along the longitudinal centre line of the concrete. Throughout all the tests the concrete had the following proportions by weight: Portland cement 1 part:

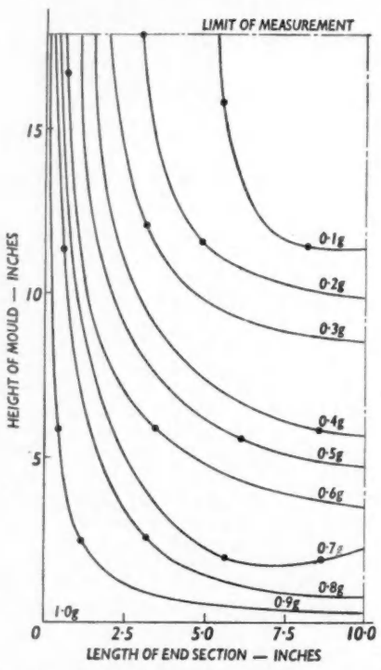


Fig. 3—Typical iso-acceleration curves for an end section of concrete mould

sand $1\frac{1}{2}$ parts : $\frac{3}{8}$in to $\frac{3}{16}$in aggregate 1 part : $\frac{3}{4}$in to $\frac{3}{8}$in aggregate $3\frac{1}{2}$ parts. (That is, an A/C ratio of 6/1.) The W/C ratio was 0·45, and the frequency of vibration in all the tests was 3000 c.p.m.

In these first tests only one channel was used, the signals from the different accelerometers being successively reproduced upon the oscilloscope screen by selection at a junction box. As was anticipated in the investigations into the mechanics of the damping processes, it was observed that a regular pattern of iso-acceleration contours was not obtained immediately upon applying vibration to the concrete. This was because, before the initial settlement of the concrete had taken place, the particles vibrate in too random a manner for any exacting analysis. Figs. 1 and 2 show typical iso-acceleration curves which were recorded in one particular test in this series. It will be noticed that the values of acceleration have been kept moderately low in most of the tests performed.

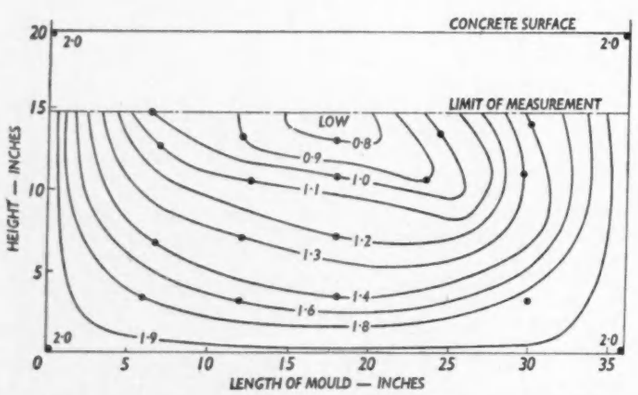


Fig. 1—Typical iso-acceleration curves at about two minutes. Values of acceleration given as multiples of *g*

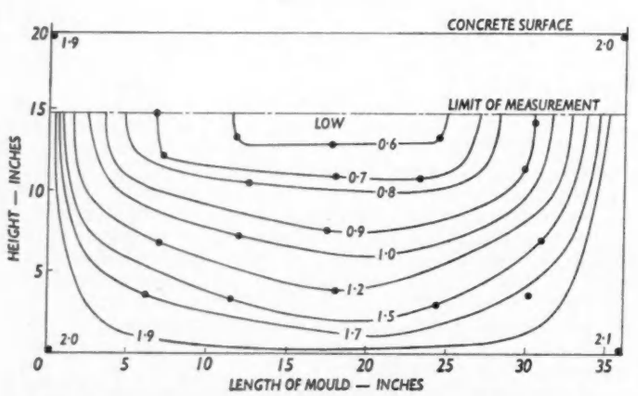


Fig. 2—Typical iso-acceleration curves at about ten minutes. Values of acceleration given as multiples of *g*

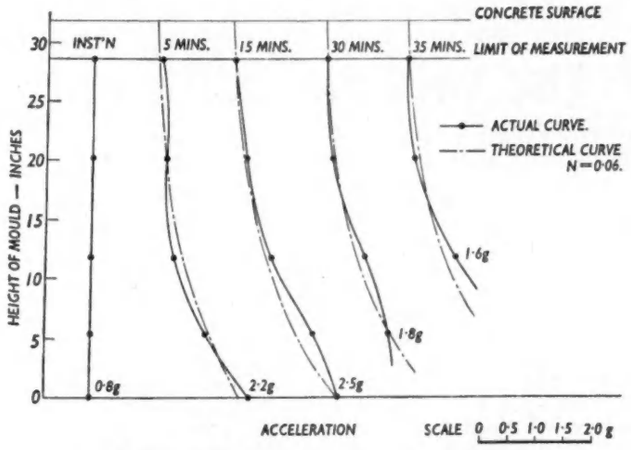


Fig. 4—Decrease of acceleration with height at different times

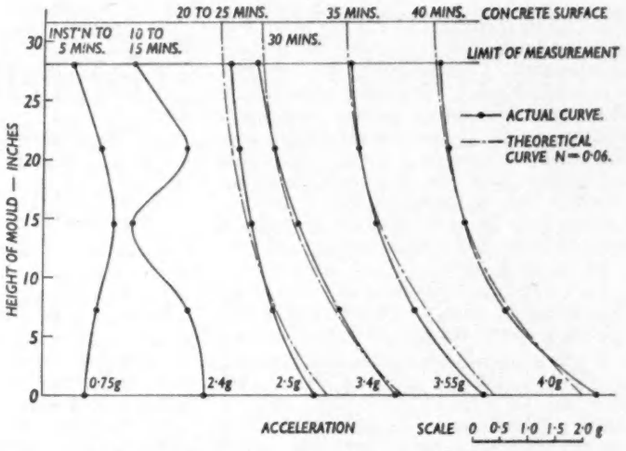


Fig. 6—Decrease of acceleration with height at different times

This practice was adopted in order to delay the compaction of the concrete and thus allow more time for measurement.

In addition to the tests carried out over the whole concrete area as described, two tests were performed to give a better idea of the exact nature of the iso-acceleration contours close to the mould itself. A typical set of curves relating to these tests is shown in Fig. 3. As a result the contours shown in Figs. 1 and 2 were able to be plotted with greater certainty.

All these curves are important in that they illuminate the manner in which the mould sides affect the transmission of the vibration waves through the concrete, and hence the way in which the mass of concrete assumes, through a reorientation of its particles, the condition of maximum density.

The second series of tests dealt with the decay of the vibration waves as described earlier. In view of the results of the first set of experiments it was decided to place the accelerometers in a single vertical line down the centre of the concrete mould, where they would be subjected to vibration waves uncomplicated by arbitrary "skin-friction" from the mould sides.

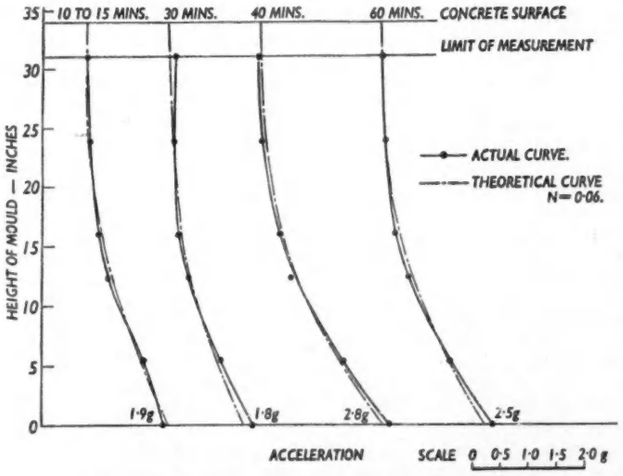


Fig. 5—Decrease of acceleration with height at different times

Using the same mix and W/C ratios as previously, tests were performed using different distances between accelerometers. Also it was decided to use three different sizes of mould, which were: 9in×9in×3ft 6in in height, 15in×15in×3ft 6in in height, and 12in×12in×4ft 6in in height. This was necessary in order to examine the effect, if any, of the proximity of the mould sides on the accelerometers, and also to yield information about the value of the constant N for different mould sizes. The only case in which the mould sides affected the measurement of the acceleration was that of the 9in square mould, when after the new inside mould surfaces had lost their initial smoothness, the multiplicity of dissimilar vibration waves gave rise to erratic accelerations.

Relative readings of the accelerations were taken at various points in each test for different times of vibration.

Unfortunately, it was found impossible to standardise the degree of vibration applied in each test, so that any attempt to compare the times of vibration between tests is invalid. However, a general pattern of behaviour can be established. It can be seen that at the commencement of each test there was a period of random vibration which defied mathematical prediction. Within a short space of time this movement settled down to give a pattern of decay close to that suggested in the developed theory.

Figs. 4, 5 and 6 show curves obtained from three of the tests in this series. On Figs. 4 and 6 can be seen the initial uncertainty in the behaviour of the concrete, followed by an increasing tendency toward the theoretical prediction. The values of acceleration given at the bottom of each curve refer to the acceleration at the lowest point on the measured decay curves and are given in terms of the gravitational constant g.

In every set of measurements taken in this series of tests the relative value of the constant N was 0·06. This would seem to suggest that the value of N is stationary for all sizes of mould using this particular mix, and perhaps even for different mix designs.

In addition to the measurements of acceleration made in this second series of tests, it was possible to estimate the variation of the wavelength of the vibration waves. Since simultaneous observations of the two waveforms from different points in the concrete could be made, the change of phase between these two waves could be obtained. From this phase difference it was possible to calculate both the average wave velocity and the average wavelength of the vibration wave between the two points under consideration. Taking these readings for a number of points in different tests, the variation of these two quantities up to a distance governed by the height of the mould could be followed.

It was found that the values of wavelength (and therefore wave velocity) fell with both time of compaction and with distance travelled. Fig. 7 gives a pattern of decrease of wavelength with time that was common to all these tests. Over three different measured lengths in the same test the values of wavelength can be seen to fall rapidly until a common time when they achieve a constant minimum value. It is suggested that if the wavelength over a specific length shortens with time, then a state of change in the material is indicated, and that when the wavelength remains constant that state of change has been completed, i.e. with a stationary value of wavelength the only large change that is occurring (viz. compaction) has proceeded to a limiting value. The

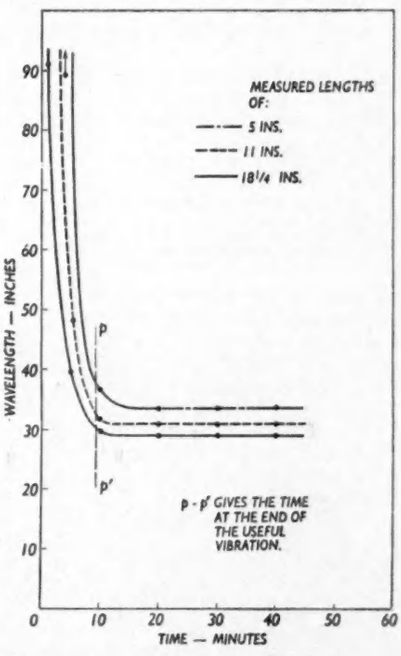


Fig. 7—Variation of wavelength with time. Typical curves for three measured lengths

effect of other changes of a lower order (e.g. cementation action, movement of the accelerometers) is considered to be unimportant in this context. Therefore it can be said that when the value of the wavelength remains constant over a given length, then the useful vibration on the concrete has been completed. The line $p—p'$ has been displaced a little to the left of the longitudinal portion in order to allow for the condition occurring before the actual measurement was taken at ten minutes.

As far as the distances in these tests were concerned the decrease of wavelength with distance showed no indication of reaching a

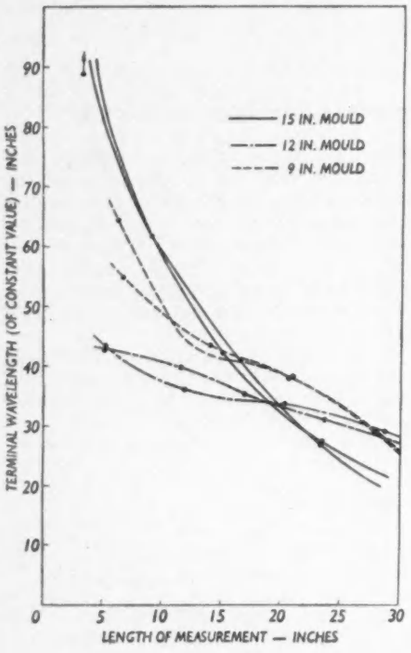


Fig. 8—Terminal (constant value) wavelength over different lengths of measurement

minimum value. Fig. 8 shows the results obtained and gives the values of the constant wavelengths at the end of the period of useful compaction, plotted against the length over which these wavelengths were obtained.

Apart from stating that the vibration waves are obviously non-linear in character, it is difficult to make a specific evaluation of the quantities involved without a more comprehensive series of experiments on this particular subject. Although this work has been carried out on one particular concrete mix, for one type of vibrational excitation in order to limit the variables, it is suggested that it is applicable, in modified forms, to other types of mix design and vibration. As such, it may be possible to apply the results of these tests to both poker and shutter vibrators operating at frequencies considerably higher than that employed by the author.

REFERENCES

[1] Plowman, J. M., "Effectiveness of Vibration of Concrete," THE ENGINEER, February 26, 1954.
[2] Plowman, J. M., "Compaction of Concrete by Vibration," THE ENGINEER, May 31, 1957.
[3] Chenea, P. F., "Application of Impedance Method to Continuous Systems," Paper No. 52.A.28, Ann. Meeting A.S.M.E., 1952.

TORQUE CONTROL SCREWDRIVER.—A new screwdriver, designed for torque control, has been introduced by M.H.H. Engineering Company, Ltd., of Bramley, Guildford, Surrey. This screwdriver, the "Torquemaster," has a tough, durable handle moulded in "Cellomold" cellulose acetate; inside this handle is a ball clutch mechanism which is adjustable to impart to the spindle any specified loading between 8 oz-in and 35 lb-in. The ¼in square drive spindle accommodates any form of nut socket or screwdriver bit.

Peaceful Use of Atomic Energy

The second international conference of the United Nations on the peaceful uses of atomic energy began on September 1. We reproduce here an abridged version of the opening address by Professor Francis Perrin, president of the conference, who emphasised the harmful effects of secrecy in scientific matters and spoke in general terms about the future of fission processes and of thermonuclear fusion.

NEVER have so many representatives, experts, or observers been sent by so many nations to compare work and exchange views on any subject. And yet the object of this conference is strictly scientific and technical and excludes all political considerations. How does it come about that so great and so widespread an interest is shown in this subject of the industrial uses of atomic energy, rather than in the great problems of demography, education or food production ? To begin with, there is the increasing need for power, particularly for electric power, in all the countries of the world. Whether in continuing the industrialisation of a highly industrialised country, or in developing an infant industry, the raising of the living standards of the mass of the people depends upon a continuous and rapid increase in the quantity of energy made available directly or indirectly to mankind for the satisfaction of its needs and for the simplification of its work. It will, therefore, be easily understood that the appearance of a fresh source of power, which seems to be unconnected with any accident of geography, should have raised great hopes in all those countries which are inadequately supplied with traditional sources of energy, and that atomic energy should have appeared to many under-equipped countries as a sort of royal road to prosperity. In fact, in the near future atomic energy can play an important part only in a fairly restricted range of countries, which does not include those countries which have the greatest need to raise their living standards. The countries which can take early advantage of atomic energy are those, already highly industrialised, which have insufficient traditional power resources to enable them to pursue their development ; a development which, given the standards already attained, requires a considerable increase in the absolute level of electric power production. This is particularly the case, sooner or later, for nearly all Western European countries, the industries of which are in danger of being held up in their expansion by a kind of asphyxia due to lack of available power, or, which amounts to the same thing, to a rise in its cost. For these countries, threatened by a relative decline, it is urgent and essential to develop large-scale electric power production on the basis of atomic energy, and this their already solid industrial foundations enable them to do. The appearance of atomic energy at this stage of their economic history is, for them, an unexpected opportunity of which they must take full advantage.

In the case of the very large countries which are already heavily industrialised and which have traditional power resources that can be developed to satisfy increasing needs, atomic energy will not for a long time have so vital an importance, despite the growth of new needs, which are the greater in proportion as industrialisation is more advanced. In these countries, industrial development may be promoted in the near future by atomic energy only in regions far from traditional power sources, such as coal mines, oilfields or water. These countries, the United States of America, the Soviet Union, essentially have only to prepare to use atomic energy on a large scale in the more remote future, when probable technical advances will have made it more economical than energy produced by cheap coal or ample water power.

Under-equipped countries, whether with or without traditional power resources, cannot, it would seem, profit from the opportunities offered by atomic energy until they have gone through a preliminary stage of industrialisation in the old way. If such a country has traditional power resources it would do better to try to make use of them, as the difficulties it must overcome (lack of capital, shortage of technicians) are even more marked in the case of atomic energy. And if an under-equipped country has no coal or oil deposits or water power that could be used economically, it would do better in most cases to import fuel (which would inevitably be expensive if it came from a long distance) and use it in traditional power plants, also imported, rather than import small atomic installations which are particularly expensive, and which would also require foreign technicians to a much greater extent. This will be the case so long as the degree of industrialisation does not allow the utilisation of large plants of several scores of megawatts, perhaps of even as much as a hundred. This conclusion remains valid even in the case of a country with uranium deposits, for atomic fuel costs relatively little in itself, and costs almost nothing to transport ; furthermore, small atomic plants operate with enriched uranium which must necessarily have been prepared in a highly industrialised country.

Nevertheless, atomic energy opens up a most promising future to under-equipped as well as to other countries. It gives the certainty that they will never be halted in their industrial development by lack of sufficient cheap power, and it guarantees the continuance of expansion. It enables under-developed countries with limited traditional power resources to embark resolutely upon a programme of industrialisation, to which it will make no contribution in the beginning, but which would have been of little value without it, because doomed to an early halt.

It is, therefore, legitimate for under-equipped countries to prepare to use atomic energy, but they should not seek to make early industrial use of it. To do this they must first train staff, which will take a long time, because in this field technicians cannot be trained until a centre of nuclear research has first been established. Such a centre is necessary to bring together, around the unfortunately expensive equipment, engineers and scientists capable of carrying out research so as to introduce the living spirit of science into the teaching of the fundamental phenomena which must be known by all those who will have to build and operate future atomic plants.

This need for the development of science before it is put to fruitful, practical use is indeed the first gain any country may expect from atomic energy. It will find in it a strong stimulus to the general improvement of

education, and to the scientific and technical training of an increasingly large proportion of its youth. An under-equipped country is essentially an under-educated country, and all countries are to varying degrees under-educated.

Foolishness of Secrecy

The greatest service rendered to the cause of peace by these international conferences is the reduction of the barrier of secrecy in vast areas of scientific or technological activity. They provide a favourable opportunity for governments to declassify areas of knowledge and thus reveal secrets which are found to be largely identical, though the discoveries were made independently. This proof of the foolishness of scientific secrecy leads in its turn to fresh declassifications which extend the field of knowledge released from secrecy. To appreciate the importance of removing, even partially, the secrecy that since the last world war has veiled scientific activities in which exchanges of ideas and publications were formerly free, it should be understood how secrecy in this field is harmful and dangerous, how much humanity loses by it, how few its advantages are to those imposing it and how serious the drawbacks that result from it for themselves. The most obvious drawback of secrecy is that it hampers and slows the progress of the sciences where it is introduced, by limiting to more or less restricted groups the exchange of ideas and knowledge which is an essential element of scientific work, and by requiring each group it isolates to carry out or repeat all the exploratory and methodological work that could have been shared out among them all. This waste of effort and lack of information harm the weakest groups particularly, as they are thus condemned to an increasing delay which may eventually render their work sterile. But it also seriously affects the strongest groups, by depriving them of results that could have been obtained by other less well-endowed groups if they had been kept informed and so could have worked along neglected directions rich in possibilities. Secrecy also harms all groups by preventing that salutary criticism which often can come only from independent groups. Finally, it should be observed that some of the most valuable men are kept away, or keep themselves away, from secret fields of research.

Yet the slowing down of scientific progress —which some people will even look upon as an admirable thing—is only the least of the evils of secrecy in important sectors of research. Its most harmful effect is to prevent science from acting as the link between men that its universal character makes it so uniquely capable of being, to engender distrust and to poison human relations in the sphere where they best allow an intermingling of civilisations.

It is often said that science in itself is neither moral nor immoral, that good or evil can only appear in the uses to which it is put, and that scientists have no reason to differ morally from other men. All this is largely true. We must not, however, disregard the influence in character formation of the practice of the disciplines of scientific research and of teaching the sciences, or even of a severe scientific upbringing. Science actually requires a perfect sincerity with oneself as well as with others, an objective pursuit of truth which goes beyond its own field and penetrates the nexus of relationships between men. It demands a discipline of thought and expression that rejects the empty emotional bombast which is so particularly apt to put peoples against each other.

To enclose important fields of research and scientific work, by preventing the men engaged in them from communicating freely with those studying the same problems in other countries, is to lose all the benefit of the mutual understanding and fraternal feeling in the same task that come with normal relations between scientists. It is a breach, in a limited but important field, of fundamental human freedoms and rights : freedom of expression and of information—the right, even the duty, to impart instruction —the right of all to learn and to know all that has been discovered on the mysteries of Nature.

That scientists suffer from frustration when obliged to work in secret was shown in very striking fashion at our First Conference, by the lively satisfaction—you might say joy—of all those who had had till then to hide their work and live in ignorance of what their colleagues were doing, when they were able to discuss it freely between themselves. The restoration of normal relations between men working in the various secret fields of research on the use of atomic energy is a notable contribution to the strengthening of peace. The importance of this contribution depends less on the number of these men, and their part in the development of major national programmes, than on their predominant position in the scientists' awareness of their special responsibility to society.

If the most valuable result of our meetings is to bring men together, we should all the more regret that a considerable segment of mankind has not been able to send its scientific representatives here, that great peoples should still be kept away from these exchanges of ideas and this rebuilding of the international scientific community. We shall suffer from it as they will, for our work of peace will be less complete.

Thermonuclear Fusion

Fission of heavy atoms is not the only source of atomic energy. We have known since 1919 that the origin of the sun's heat, and, in general, of energy radiated by the stars, can only be the fusion of light atoms into heavier, especially of hydrogen into helium atoms. This fusion of light atoms takes place in the interior of stars by thermonuclear reactions made possible by the very high temperatures obtaining there. The achievement of even higher, but momentary, temperatures on earth by the explosion of atomic bombs has enabled these thermonuclear fusion reactions to be primed, at least between atoms of heavy hydrogen, deuterium or tritium. This is the way in which the bombs called hydrogen or thermonuclear bombs have been made, and they are far more powerful than bombs utilising fission only.

The president of the First International Conference on the Peaceful Uses of Atomic Energy, Professor Homi Bhabha, in his remarkable opening address hazarded the prediction that ways of controlling the liberation of fusion energy to make it industrially usable would be found in less than two decades. Nothing had then been published on the first steps towards that goal, and secrecy continued to be imposed without any visible good reason on research into the production of fusion reactions by non-destructive methods. This research was nevertheless far removed from techniques that could be used for military purposes, and probably also from any practical application in the future. Here we have a striking example of the evil that can be done by the habit of wrapping up in secrecy all research even remotely connected with the military use of atomic energy. A most excellent piece of work could be published only in part and with delay, in circumstances which led politicians or journalists to seize on it and subject it to far-fetched interpretations for propaganda purposes. And this could happen because there was no time left in which this work could take its rightful place in the advance of science by a comparison with results obtained elsewhere and a free discussion among specialists.

However incomplete so far the information released in this field, we already know that in the past three years astonishing progress has been made towards obtaining conditions in which the production of controlled fusion reactions can be expected. The prediction of my predecessor seems well on the way to being fulfilled, although we perhaps judge better, after what has been done, the difficulty of what remains to be done. Whatever the case I think that a main achievement of the Conference opening to-day will be that it will have been the occasion of the complete elimination of secrecy in this last outpost of controlled fusion where it still reigned ; the communications on this subject will be by far the most striking revelation of our meetings. Another achievement will be the spectacular presentation of devices permitting the temperature of gases to be raised to several million degrees, a temperature at which thermonuclear fusion of heavy hydrogen atoms begins ; this will be the great, the crowning event of the Scientific Exhibition associated with our Conference.

The Continued Importance of Fission

This progress towards the taming of the fusion energy of deuterium, inexhaustible reserves of which exist in ordinary water, might lead one to suppose that the fission energy of heavy atoms will only be a transitory source of energy, and that the plants utilising it, which will multiply in the next few years, perhaps even run the risk of being obsolete before their depreciation value has been written off. I think that this is not so. I have every confidence in the final success of the work of physicists and engineers engaged in this difficult task, especially as it will be carried out now with world-wide co-operation. But I think it will take many years for practical results to be obtained. First of all, several years, ten or so perhaps, will be needed to devise and construct apparatus in which fusion reactions will be produced between atoms of heavy hydrogen yielding a large amount of energy in proportion to that wasted in stimulating or starting off these reactions, without destroying the apparatus, so that the operation can go on or be repeated. However remarkable the technical success of such apparatus, it will certainly still be a long way from any successful industrial plant for which the total cost of the energy produced will have to be brought down to the level of that of other methods of power production, including fission. In this total cost the cost of the new atomic fuel, heavy water, will assuredly be almost negligible. But this will be so too with uranium, when we are able to utilise it completely by breeding plutonium ; this will probably happen before we can control fusion. What will count most in the cost of energy produced by fusion will be the costs of the operation, maintenance and depreciation of installations ; these must be successfully reduced, just as at present all efforts to make fission energy an economic proposition tend to do. But the difficulties will, it would seem, be much greater if you think of the complicated apparatus that will undoubtedly be required

merely to produce the conditions for controlled fusion, and if you compare it with the extreme simplicity of the conditions for production of fission energy, for which it is sufficient, for example, to pile up bars of natural uranium and bricks of pure graphite without any great precision.

The prospects of energy production by controlled fusion should therefore not lead us to cut down our efforts to utilise fission energy. This alone can make up for the increasing inadequacy of traditional power sources for the next twenty odd years, and perhaps for a great deal longer. But the prospects can calm our fears about the future of humanity, and free us from remorse at the thought of exhausting the easily exploitable uranium deposits in a few thousand years.

It is, however, probable that industrial utilisation of fusion energy will develop, at least to begin with as in the case of high powered fission-fusion-fission bombs, as a method of direct liberation of the fission energy of uranium 238 or thorium through the action of fast neutrons. As a result, even then uranium will remain, with thorium, as the basic raw material of the new sources of energy. While this is the case we shall not be able to dispense with the precautions needed in utilising or disposing of radioactive waste with a long life derived from the fission of heavy atoms.

Waste Disposal

The problems raised by the existence of this radioactive waste, and the general dangers to which very extensive expansion in the industrial utilisation of atomic energy may expose populations of varying sizes by subjecting them to ionising radiation, even of low intensity, should receive particular attention on the international level. The multiplication of artificial sources of ionising radiation is part of the changed conditions of life which are a feature of the atomic age. We must accustom ourselves to a life which takes these new dangers into account, and we must get to know more about them so as the better to escape them. The United Nations Organisation, two and a half years ago, entrusted a committee of experts with the collection of information, which is still very incomplete, on the long-term biological consequences of prolonged irradiation, even of low intensity, of individuals and populations. This committee released a few weeks ago its final report which is to be submitted to the next General Assembly of the United Nations. It appears from its work that any considerable increase in the average amount of radiation received, over and above the inevitable radiation mankind has always been subject to from cosmic rays and natural radioactivity, may perceptibly increase the likelihood of the appearance of leukæmia or cancer in the individual and the number of abnormal births in future generations. Here we do not have to consider the implications of this report on the assessment of the dangers of the accumulation of radioactive fallout from experimental atomic explosions, or on the limiting of the medical use of X-rays. But we should find in this work a basis for fresh amendments to the rules for the protection of those working on atomic energy and a confirmation of the need for international regulation of the disposal of radioactive waste in rivers, seas or the atmosphere. Only if the governments responsible for the protection of individuals and populations continue with the utmost vigilance to draw up and impose the necessary regulations will it be possible to look forward without apprehension to atomic energy becoming the chief source of energy for all mankind.

Developments on the "Spacematic" Jig Boring Machine

The automatic positioning "Spacematic" jig boring machine designed and built by the Newall Engineering Company, Ltd., and incorporating the B.T.H. electromagnetic measuring system, is now available with some interesting new equipment. In addition to a two-dimensional tracer control unit and an auxiliary horizontal boring spindle, it can be arranged for what is termed "staircase" milling, by which two-dimensional profiles can be quickly and easily cut to very close tolerances.

WE recently attended a demonstration of the "Spacematic" jig boring machine to see some interesting new equipment that the Newall Engineering Company, Ltd., Old Fletton, Peterborough, has developed to extend the range of application of the machine. This machine was described in some detail in our issue of June 29, 1956, and it will be recalled that it provides automatic table positioning to give rapid, accurate work location without need for calculation of co-ordinates by the operator. The machine incorporates an electromagnetic measuring system which was specially developed by British Thomson-Houston Company, Ltd., and is sensitive to fifteen millionths of an inch. Automatic control is imparted by punched cards which institute and determine the precise amount of table movements, both slides being set simultaneously. The latest design of machine, to be seen in the illustration on this page, incorporates equipment for "staircase" milling, controlled copy milling and an auxiliary horizontal boring spindle.

In introducing the "staircase" milling technique on the machine, the makers point out that it is a new economic approach to continuous numerical control when producing high accuracy profiles by jig boring methods. Hitherto, two-dimensional profiles have been produced by taking a large number of closely spaced cuts at successive co-ordinates so as to produce a number of points lying on the required curve. Surplus metal left between settings has then to be removed by hand, although, depending upon its significance, closer spacing of cuts may avoid this necessity. With the new equipment the introduction of automatic positioning from information punched on cards has simplified this method of working for two reasons: first, automatic positioning combined with automatic card reading allows a very high rate of cutting (up to six points per minute) compared with that achieved by hand setting; secondly, the tedium of such an operation, which frequently led to the operator making a faulty setting when the job was nearing completion, has been eliminated by the combination of punched cards previously checked, and automatic positioning.

The further development of this technique of "staircase" milling, applied to the "Spacematic" machine, allows a milling cut to be taken during the actual auto-positioning cycle. When using this method, the table moves to successive positions along alternate co-ordinates, the slide which is to move first being determined by an additional hole in one of two columns on the punched card. The method of approach is not the same as in normal co-ordinate positioning on the machine, in that the final 0·02in approach is omitted, the table moving directly to its selected position. After the card reader start button on the control panel has been depressed, the machining process continues

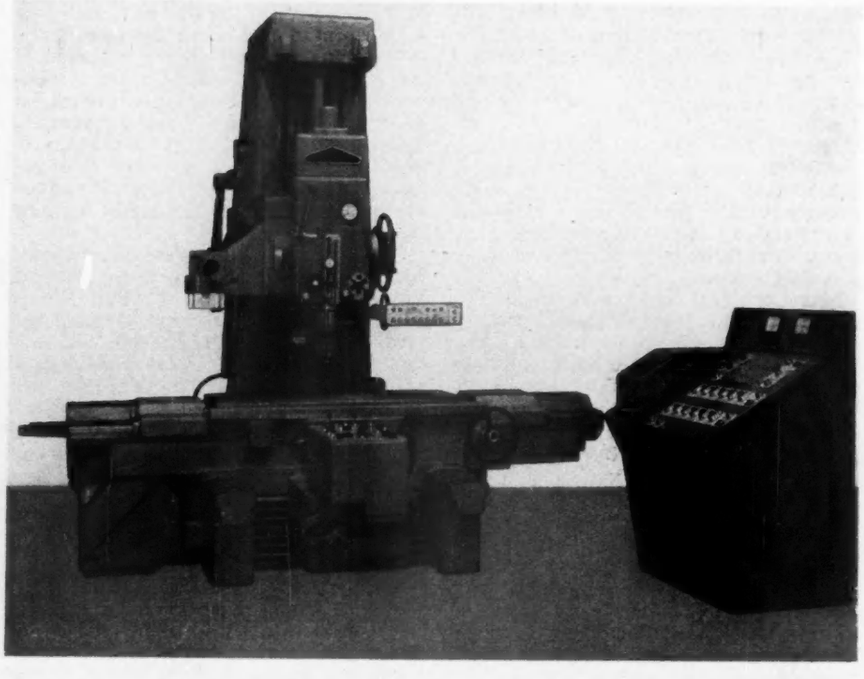


Fig. 1—"Spacematic" jig boring machine with tracer control and "staircase" milling equipment

automatically until completed. The machining procedure can be followed with reference to the diagram reproduced in Fig. 2. When the first card has been read, the above-mentioned additional hole punched in the

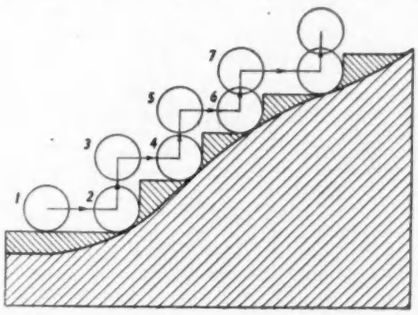


Fig. 2—Diagram showing the method of "step" cutting in "staircase" milling

card comes into effect and causes the appropriate slide to feed and move the work from cutter position 1 to position 2. This slide is then clamped automatically and the other slide unclamped to feed the work until cutter position 3 is reached. On this slide then being clamped the card reader inserts and reads the next card which initiates the whole cycle once again.

By this "staircase" method it is possible to obtain up to six contact points on the curve in one minute at a maximum feed rate of about 4in per minute. This rate is steplessly variable down to about ¼in per minute, to allow machining of hard materials, but this has little effect on the production rate if successive steps are small; in all cases the feed rate drops over the last few thousandths inch of travel. It is also possible to generate three-dimensional forms by this method, the machine spindle being moved to successive vertical positions suitably spaced and successive "packs" of cards being used at each height setting.

From the above notes it will be apparent that as the distance chosen between successive points tends towards zero, the process approaches true path numerical control. It should be appreciated, however, that if the distance between steps is reduced to the order of a few tenths of thousandths of an inch, the production rate may well become uneconomic, although the accuracy will be of an extremely high order. On the other hand, thoughtful planning, whereby the co-ordinate spacing chosen is related to the radius of curvature of the work, the cutter diameter, and the quality of finished surface required, will permit the use of quite large intervals and produce a suitable surface.

An interesting example of machining a curved profile by this method, which we were shown at the demonstration of the machine, consisted of an 18in by 6in piece of ½in gauge plate out of which a curved section of 5½in radius had been milled. For this job a 1·25in diameter cutter was used and the machine set for a co-ordinate spacing of 0·08in for the roughing and 0·002in for the finishing cuts. The height of "ripple" on the finished surface was 0·00008in and the accuracy was stated to be within ±0·00015in from true form.

It is recommended that a punch card sequence checker should be fitted to the control desk when the equipment is fitted on a machine. This checker is a safety measure which comes into effect to stop the machine should a punched card be presented out of its proper sequence. By operating appropriate switches on the control desk, the basic pack of punched cards required for a given profile can be also used to produce opposite-handed, or mirror image, versions of the same form. The few necessary controls for "staircase" milling are located either on the standard machine console or control desk and the equipment permits profiles to be generated of a size equivalent to the maximum working capacity of the "Spacematic" machine, 26in by 44in.

In our note on the "Spacematic" machine shown at the European Machine Tool Exhibition in the issue of September 27, 1957, mention was made of a prototype two-dimensional tracer control which allows copy milling to very close tolerances. Extensive trials have shown the suitability and advantages available from this equipment which can now be fitted to the machine as a standard. The B.T.H. tracer head which is used can be seen in Fig. 3 and its adoption is advantageous in that a considerable proportion of the electrical equipment used for automatically positioning the jig borer table can also be utilised for copy milling.

A feature of the B.T.H. tracer head is that it steplessly follows the profile; the total vector speed of the cutter in relation to the work is constant, and the direction of the cut is such that the stylus is maintained in contact with the template at constant pressure of 4 oz. Under satisfactory operating conditions it is stated to be possible to maintain a copying accuracy better than 0·0005in. The tracing speed is steplessly variable from ¼in per minute to 6in per minute, and a

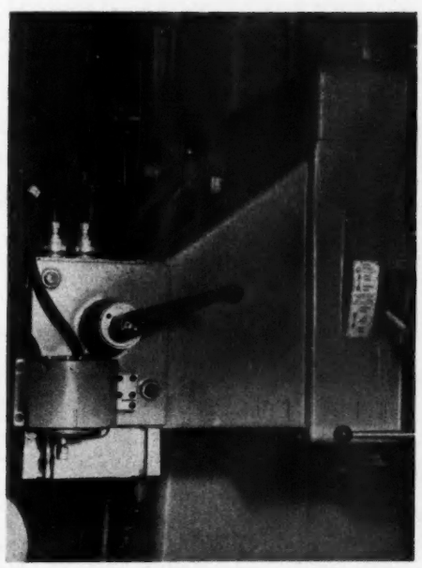


Fig. 3—Two-dimensional tracer control unit for copy milling

further speed range of 6in to 36in per minute can be used in conjunction with a manually operated steering control.

The direction of traverse may be selected so that either conventional or "climb" milling may be performed, special backlash eliminators being incorporated in the table drives. Change-over from nominal automatic positioning to tracer control is effected by operating one switch only, so that components having profile surfaces in addition to precise bores or rectilinear surfaces can be machined at one setting.

The control station is incorporated in the console on the front of the machine and an auxiliary model table having a 2in (51mm) adjustment along two right-angular co-ordinates is mounted, overlapping the ways guards at the left-hand end of the machine table. To ensure maximum rigidity of the tracer head (which has a direct bearing on copying accuracy), the copying area is limited

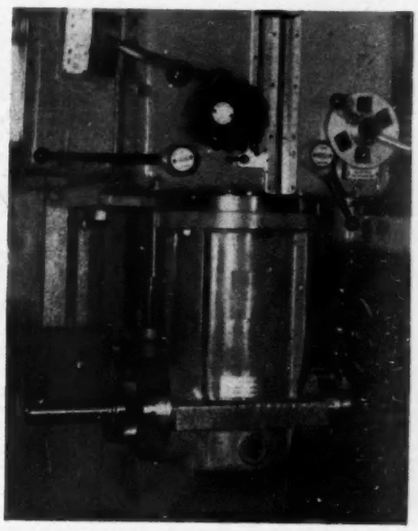


Fig. 4—Auxiliary horizontal boring spindle head fixed to the base of the machine feed box

to 26in by 26in but, by special arrangement, it may be possible to increase one of these co-ordinates.

The new auxiliary horizontal boring spindle attachment which can be fitted to the machine is illustrated in Fig. 4. It comprises a horizontal spindle mounted in a casting which is fixed to a precision surface on the base of the machine feed box. Drive is taken from the heavy duty main jig borer spindle through a coupling and a pair of bevel gears giving a steplessly variable speed range up to 2000 r.p.m. The 2⅝in diameter horizontal spindle is similar to the Newall 2436 jig borer spindle and is mounted in S.K.F. precision, double-row cylindrical roller bearings housed in journals. The spindle nose has a 10 deg. included angle taper bore and a captive nut, a quarter turn of which serves both to clamp and extract tools.

Height adjustment of the horizontal spindle centre is accomplished by raising or lowering the jig borer feed box. If large distances are to be moved the rapid electric traverse may be engaged, final adjustment being made manually. For this purpose a hand-wheel, giving 0·05in feed per revolution and calibrated with fifty divisions to provide 0·001in adjustment, is employed; for height establishment to finer limits a dial indicator provides measurements to 0·0001in. The hand-wheel operates through the normal traverse lead screw, with which it has clutch engagement, and a safety interlock prevents motor traverse when the clutch is applied. A further interlocking switch is brought into operation when the unit is fitted to the machine in order to prevent mechanical traverse of the jig borer quill. The horizontal spindle feed rates are governed by the table feed rates which are steplessly variable over the range of ¼in to 12in per minute.

ANTI-TANK WEAPON.—It is now known that the anti-tank guided missile projected for the British army and expected to "remove the heavy tank from the battlefield" is being built and developed by Fairey Aviation Company, Ltd. The weapon is known to be wireless, and the experience of the designers with the "Fireflash" suggests that beam-riding will replace the command guidance almost universal among such missiles.

SHORTER REPORTS

The Radio Show

THE RADIO SHOW which ends to-morrow at Earls Court, London, is, as usual, mainly a shop window of British-made receivers for sound and television broadcasting. For many years past, technical and topical interest has centred on television but this year developments in stereophonic sound have focused attention on the audio frequencies. Many commercial models of stereophonic "radiograms" are to be seen. Most of the stereophonic receivers are of two-unit design. Other radiograms are wired for "stereo" so that a plug-in stereophonic head and an additional amplifier loudspeaker unit can be added later. There is a stereophonic bowl speaker 8½in in diameter designed for use as the second speaker with a number of stereo systems. Many "transistorised" portable sets are on show. Among the more exotic examples is a portable receiver in the form of a book 7½in by 5½in by 2½in in various bindings, the covers of which contain two dials, a 2½in diameter loudspeaker and circuitry consisting of six transistors and a germanium diode taking power from a 9V battery.

Most of the television receivers show refinements in detail rather than revolutionary changes. One set, for example, has four push-buttons for inter-channel switching. Another receiver, with a 21in screen, makes use of printed circuits.

For visitors who may be interested in the older and more prosaic modes of radio communication, there is much of interest in the displays that occupy the whole of the first floor. One exhibit organised by the Radio Industry Council, with the help of the Northern Polytechnic and Wimbledon Technical College, illustrates careers in electronics. It includes a working model of the radio telescope at Jodrell Bank, Cheshire, together with specimens of sound and vision recordings of signals received from the "Sputniks" by the radio-telescope at Cambridge. These exhibits form a background to a technical training display and an inquiry bureau for careers in electronics.

Progress in radio and electronics during the last half-century is strikingly exemplified in the display by the Royal Navy. The history of radio at sea is traced in a series of exhibits beginning with a replica of the first radio set carried on a naval craft. It was designed by Captain H. B. Jackson, R.N. The transmitter was an induction coil producing a 6in spark in dry air from a primary voltage of 12–24V; the receiver was a separate aerial and coherer. With this apparatus, in 1895, communication was made by Morse at the rate of eight words per minute over a distance of 5800 yards between H.M.S. "Defiance" and "Scourge." The next exhibit marks another landmark, the Mark I, 1½kW spark transmitter developed by Marconi and Jackson in 1908 and installed on H.M.S. "King Edward VII." Typical radio offices on warships of 1928 and of 1958 complete the history. The enormous growth in complexity of equipment over two decades is well-summarised by the fact that the value of the electronic installation in an aircraft carrier was £12,000 in 1938 and is over £1,000,000 to-day.

A display of guided weapons forms the basis of the Royal Air Force exhibit. There is a full-scale replica of the "Bloodhound" ground-to-air missile, a scale model "Thunderbird" and specimens of "Fireflash" and "Firestreak" missiles. Like the Royal Navy, the R.A.F. show emphasises the technical opportunities open to girls as well as boys in the very specialised defence systems of to-day.

Exhibits on the Post Office stand show how progress in electronics is used to improve automatic telephony and letter-sorting. Here the Electronic Letter Sorting Indicating Equipment (which was described in our issue of August 15, 1958) can be seen at work. This machine costs £15,000 and with it letters can be sorted into 144 destinations at a rate of 600 letters an hour.

Group Hearing-Aid for Schools

WE learn that an improved form of group hearing-aid for use in school classrooms has been developed by the chief engineer's department of the London County Council after a critical assessment of apparatus that has been in use in London schools for many years. The engineering problem was to provide high-fidelity sound of sufficient intensity, with flexibility of control to enable each child to hear the teacher and other children in the class. To do this effectively it was decided that every child should have separate control of the volume of sound reaching each ear and that the teacher should be able to control the signal strength from each of the individual microphones used by the children. Important requirements were that every piece of apparatus should be simple and reliable with some degree of mobility and that the whole installation should be easily dismantled when the room is required for active work.

The system adopted to meet these needs is suitable for classes not exceeding twelve pupils. It is based on a high quality mains operated amplifier with an overall gain exceeding 110 dB and fitted with separate controls for bass and treble boost. Provision is made for the input of a tape recorder, a four-speed gramophone record player and sound from a 16mm ciné projector. The amplifier output is connected to the line by a 1 : 1 double-wound output transformer. A 12-way electronic microphone mixer unit provides individual control of the input level to the main amplifier from each pupil's microphone.

The amplifier and microphone mixer are housed in a wooden cabinet mounted on castors, as illustrated. The electrical equipment is completely enclosed within the ventilated cabinet with only the twelve microphone control knobs exposed for adjustment by the teacher.

Normally the cabinet is kept at the side of the teacher's desk but it can be moved within a radius of 9ft. It also houses a four-speed record player and a f.m. radio tuner unit, either of which can be played through the system as and when required. An input equalising unit mounted on top of the motor board enables the teacher to control either gramophone, radio, tape recorder or microphone input.

The pupils' desks are usually arranged in horseshoe formation round the teacher's table. Each desk is fitted on the underside with two control units so that the child has right- and left-hand control over the volume of the right and left earpiece of the pair of headphones. There are similar controls for the teacher's use on the main unit.

The thirteen microphones, one for each pupil and one for the teacher, are high quality, moving-coil units, supported by a flexible swan-neck stem mounted on a spigot, flush with the desk top. Connection to the desk socket is made by two-core p.v.c. insulated metallic sheathed cable.

Headphones for the pupils and teacher are "Permoflux" moving coil equipments, fitted with chamois leather ear cushions to prevent acoustic feed-back with the pupil's microphone and to reduce discomfort to a minimum. The lead from each pair of headphones terminates in a three-pole, non-reversible plug for connecting to the desk control unit.

Wiring between the desk units and the amplifier is carried out with two-core, screened p.v.c. insulated-and-sheathed cables to reduce inductive coupling between the amplifier output and the microphone lines. The cables are run under the floor in a system of ducts terminating in floor traps to simplify maintenance and give mobility and ease of dismantling.

Some classrooms in which the new equipment has been installed have ⅛in thick rubber floor tiles laid on a latex screed, the walls being covered with 24in by 12in 1½in thick Burgess acoustic panels consisting of perforated pressed steel zinc-coated trays with mineral wool infill from ceiling to dado level. The ceilings are lined with 12in square 1in thick "Paxtiles" consisting of asbestos fibre faced with perforated asbestos millboard and supported on battens.

The cost of a group hearing aid for a teacher and twelve pupils, including installation, is stated to be about £350.

Class of partially deaf children using the group hearing-aid developed by the London County Council. Each child has a microphone on a swan neck mounting and a pair of headphones with individual control of right- and left-hand earpieces. An input equalising unit in the amplifier cabinet enables the teacher to select either gramophone, radio, tape recorder or microphone input

The " Power Major " tractor is shown here operating a cultivator with spring-loaded tines

51·8 B.H.P. Tractor

NEARLY seven years ago (THE ENGINEER, November 30, 1951), the Fordson " Major" tractor was introduced by the Ford Motor Company, Ltd., Dagenham. It was designed as a medium-powered machine, the diesel-engined version giving up to 41 b.h.p. at an engine speed of 1600 r.p.m. Petrol and vaporising oil-engined versions of this tractor were also available. In the intervening years various improvements in this tractor have been effected, as, for example, in 1956 (THE ENGINEER, November 30, 1956) when a double clutch assembly was made available to give live power take-off and hydraulics and a power-assisted steering system was introduced. In recalling the progress of the " Major," the Ford Motor Company, Ltd., has recently stated that nearly 264,000 of these tractors have been produced.

It has now been decided to discontinue the production of the tractor in its original form. That decision is in line with the trend, which has been evident for some time, towards increased power in tractors in the medium class. Agricultural users call for more power from the belt for operations such as threshing and baling, greater power for driving forage harvesters and similar attached machines, and more drawbar power for heavy ploughing. The same trend is noticeable in the many industrial uses for which tractors, designed basically for farm work, are now employed. The successor to the " Major " as originally designed is the " Power Major," which is illustrated herewith, and which went into production at the Dagenham plant early in August. The diesel-engined version gives 51·8 b.h.p. at 1600 r.p.m. The engine is a four-cylinder o.h.v. unit, 3·937in bore and 4·524in stroke, with a capacity of 220 cubic inches and compression ratio 16·1 : 1. Compared with the former " Major " engine, there have been alterations to the rocker arms, camshaft, cylinder head and the fuel injection system ; a sensitive pneumatic governor regulates the fuel supply to the direct four-hole injectors. The five-ring pistons are recessed at the top to form, with the cylinder head, suitably shaped combustion chambers, and to cope with the additional power rating an extra large diameter air cleaner is fitted. A petrol-engined version of the tractor is also available.

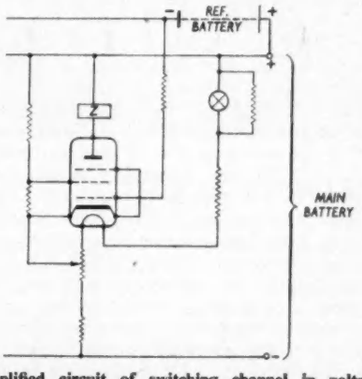
The modifications to the engine have necessitated various changes in the differential which has been improved by incorporating " revacycle " pinions. The gearing provides for six forward road speeds between 2·07 and 13·16 m.p.h. and two reverse speeds of 5·03 and 2·80 m.p.h. The power take-off drive is carried throughout on ball and needle roller bearings. In the hydraulic system of the tractor, the former unloading valve has been replaced by a relief valve which reseats immediately on a slight fall in pressure. Another refinement is the fitting of scalloped rear wheels, the object here being to reduce effort in adjusting the wheel track by eliminating the need for removing the disc completely from the axle when making certain changes. The front axle is a pivoted three-piece construction, the track adjustment being from 50½in to 74½in in 4in steps.

The driver's task is eased by a repositioning of the instrument panel and controls. The instrument panel of the " Power Major " is placed on top of the tank, below the steering wheel. The main control switch, lighting switch, stop control and proof meter are included in the instrument panel. The throttle lever is located under the steering wheel, in a similar manner to that of the " Dexta " tractor (THE ENGINEER, November 29, 1957).

The " Power Major," it may be added, is not exclusively a wheeled tractor. Like its predecessor, it will be available with either " County " or " Roadless " tracks.

Electronic Control of Voltage Compensation of Signalling Battery

RAILWAY signalling apparatus that is operated from a central battery with automatic charging may be subject to considerable voltage variations between the near-discharged state under load and the final state of the battery before charging is interrupted. An electronic system for restricting these variations by the automatic switching of counter-e.m.f. cells has been developed by



Simplified circuit of switching channel in voltage stabilising system for railway signalling batteries

The Siemens and General Electric Railway Signal Company, Ltd., East Lane, North Wembley, Middlesex, and is in use in C.T.C. (Centralised Traffic Control) installations carried out by the company.

In this system of voltage compensation groups of counter-e.m.f. cells are brought into circuit at three preselected voltages during the rise of battery voltage on charge, and are short circuited at three slightly lower voltages during discharge, the difference being of the order of 1V or 2V. Control of the switching is effected by pentode valves which conduct and energise relays when their anode voltage (derived from the main battery) attains certain values relative to a fixed reference voltage applied to the grids.

The diagram shows (omitting counter-e.m.f. cells) the circuit for one of the switching channels. The main and reference voltage batteries are connected in opposition and, assuming a forty-eight-cell main (50V nominal) battery, the reference battery would be 45V and the grid voltage would be 5V positive with respect to full negative. The grid is, however, held normally negative to the cathode by connecting the latter to a point in the heater resistance chain, which can be adjusted to set up the conditions required in each channel.

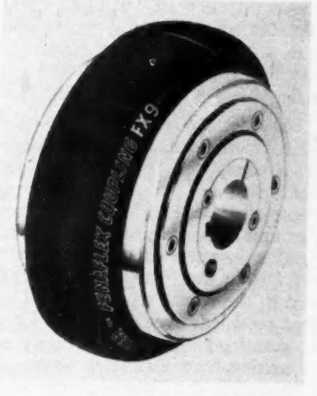
As the main battery voltage rises on charge, the increasing difference between main and reference battery voltages reduces the negative grid bias and eventually allows sufficient anode current to flow to energise relay Z ; the closure of relay Z contacts (not shown) completes a circuit through a contactor operating coil and when the contactor contacts open, the first group of counter-e.m.f. cells is brought into the supply circuit. When the main battery voltage falls, the counter-e.m.f. cells are short-circuited at a valve current of about 2mA.

The two other channels, each controlling two more counter-e.m.f. cells, operate similarly, but switching-in takes place at successively higher main battery voltage levels, as governed by the settings of the cathode bias potentiometers. Yellow indicator lamps are illuminated when the counter-e.m.f. cells are in circuit, and blue lamps continuously prove the integrity of the heater circuits.

The apparatus is operated under conditions that favour long life of its components. The valves are run at much below their normal anode and heater ratings. Negligible load is imposed on the reference battery : even if the grids are driven positive by the rising main battery voltage, the grid current taken by each valve is stated to be only a fraction of a milliampere.

Flexible Coupling

WE illustrate a new form of flexible coupling now being made in eight sizes by J. H. Fenner and Co., Ltd., Marfleet, Hull, for transmitting up to 20 h.p. at 100 r.p.m. The coupling consists essentially of a rubber tyre to each side of which are bonded twin flanges. These flanges, through the firm's design of " Taper-Lock "



Rubber tyre flexible coupling

shaft units, are coupled to the respective driving and driven shafts.

The degree of flexibility in the rubber tyre provides for angular and parallel misalignment of the shafts and a degree of end float. The tyre further cushions shock loads and reduces torsional vibrations when plant is running. In the event of the rubber tyre splitting the coupling can be replaced without need for moving the driving or driven machines.

Industrial and Labour Notes

Engineering Wages

Last week, the Engineering and Allied Employers National Federation replied to the claim, submitted in June, for a 6 per cent increase in the wages of workers employed in the engineering industry. At a meeting with representatives of the Confederation of Shipbuilding and Engineering Unions, a statement was presented explaining in detail the employers' inability to meet the demand. Among other matters, this statement pointed out that many engineering firms could not face any increase in wage costs and that employers were not willing to take any step which might increase the danger of unemployment.

During the meeting, Sir Kenneth Hague, president of the employers' federation, emphasised that engineering firms could no longer pass on the cost of wage increases by raising their prices ; it was essential that they should be able to sell their products competitively if the industry was not to decline. But he suggested that the meeting should go " into committee " so that efforts could be made to settle the dispute. Sir Kenneth asked, however, that any settlement reached should be on the understanding that there would be no further claim for a year. This suggestion was acted upon, and the ensuing discussions between the two sides resulted in an offer by the employers of 5s. 6d. a week for skilled men, 4s. 6d. for unskilled, and 5s. for intermediate grades. This offer, however, which represents an increase of about 3 per cent on current rates, was rejected by the unions. In view of this rejection, the employers' representatives said that they could not proceed with an earlier offer to increase holiday pay. At the same meeting, the union confederation's claim for a gradual reduction in the working week from forty-four to forty hours was rejected by the employers' federation.

The reply of the Shipbuilding Employers' Federation to similar claims submitted for shipbuilding and ship-repairing workers is to be given on September 9. A conference of union executives, convened by the Confederation of Shipbuilding and Engineering Unions, is to be held on September 11 to consider the replies of the two employers' federations.

Dockers' Wages

An offer by port employers in Great Britain to increase dock workers' wages by 7s. 6d. a week was accepted last week by representatives of the docks group of the Transport and General Workers Union and of other unions concerned. There is to be a comparable increase in pieceworkers' rates. The offer is in line with a recommendation included in the recent report of the Court of Inquiry, presided over by Lord Cameron, which examined the circumstances of the dispute arising from a rejected wage claim.

On this point, the Court's report says that if discussions in the National Joint Council for the Port Transport Industry had centred on a figure which would have produced an addition of approximately 7s. 6d. a week on the basic time rate, with a consequent adjustment of piece rates, grounds might have been found for an agreement which would not have been out of line with recent major industrial settlements, or out of accord with the present trend of wage negotiations. The report adds that in mentioning this figure, the Court makes it clear that it is not suggesting that " peace must always be bought at whatever price may be demanded." Another comment in the report is that " an opportunity of improving relations at all levels in the docks may have been lost by failure to explore in the National Joint Council the possibility of introducing or improving benefits and amenities which the unions have, in the past, tried to obtain."

Changes in Wage Rates

The Ministry of Labour has reported that changes in wage rates which came into operation in the United Kingdom during July resulted in an aggregate increase of about £260,000 in the weekly full-time wages of 1,238,000 workpeople. Decreases aggregating £13,500 a week were made, under sliding scale agreements, in the wages of about 115,000 workpeople.

In the first seven months of this year, changes in wage rates led to an increase aggregating £1,404,600 in the weekly full-time wages of 4,903,500 workpeople. In the comparable period of 1957, there was an aggregate increase of £4,199,000 in the weekly full-time rates of 10,218,000 workpeople. At the end of July the index of rates of wages (January 31, 1956=100) was 114 for all workers in all industries and 113 when the manufacturing industries only are considered. In the latter category, the index has been static since March.

Manpower Movements

In the August issue of *Bulletin for Industry*, the information division of the Treasury discusses the trends in employment in Great Britain during the first half of this year. It points out that over 23,000,000 people were estimated to be in civil employment at the end of June. Although that was 165,000 less than a year ago, 1957 was the only year in which the mid-year employment figure was significantly higher than this year. Compared with a year earlier, the main changes in civil employment at mid-1958 were falls of 152,000 in manufacturing, 24,000 in building and contracting and 23,000 in agriculture, with a rise of 57,000 in distribution and other services. There were 110,000 fewer women in the manufacturing industries (3½ per cent) and 42,000 fewer men (less than 1 per cent). The decreases, the *Bulletin* comments, have been widespread but mainly quite small.

The *Bulletin* goes on to say that the figure for unemployment usually falls in the first half of the year and is at its seasonal lowest in July. This year, unemployment in July, at 412,000 (1·9 per cent), was still 16,000 more than in January, and 168,000 more than in July, 1957, but between May and July of this year there was a fall of 36,000. Usually, there is a rise in unemployment from July to the end of the year, as activity falls off in the seasonal trades such as agriculture and building. The regional returns show considerable variation. Unemployment in July was 1½ per cent or less in London and the South East and in the Midlands, Eastern and Southern regions, where almost half the labour force of Great Britain is employed. In the East and West Ridings, South Western and Northern regions, where 20 per cent of the total labour force is employed, unemployment was between 1½ and 2 per cent. Unemployment (at 3½ per cent) was markedly above the national average only in Scotland and Wales.

The *Bulletin* refers to the examination which has been made recently of areas in Great Britain identified as having a serious and continuing unemployment problem. Although their insured employees are less than 7 per cent of the total for Great Britain, they account for 17 per cent of the national total of unemployed. Most of these areas have one thing in common in that they are deficient in the manufacturing industries which have been expanding nationally. The measures announced at the end of July (THE ENGINEER, August 8, page 231) have been designed to assist areas of this kind, with a persistent unemployment percentage of 4 per cent or more.

Steel Industries of the World

The British Iron and Steel Federation has published this week a report entitled " Who Owns the Steel Industries of the World ? " A survey shows that the public ownership of steel companies is confined almost entirely to the Communist countries, where they are part of fully-planned collectivist economies. Only 5 per cent of crude steel output, outside the U.S.S.R., Eastern Europe, China and Korea, is produced in publicly-owned works, and even this proportion, the report points out, is the result of special circumstances. It is highly significant, states the report, that having regard to the political developments of this century, the steel works of the free world are still almost universally privately-owned. This, it suggests, is undoubtedly based on the recognition that steel industries, in free countries, are unsuitable for state ownership and on a refusal to jettison the benefits of financial and managerial autonomy in this sector of the economy.

A growing majority of opinion in the democracies favours private ownership and public supervision of the steel industry, it is stated, a system that already exists in most of the countries concerned, although the method of public supervision varies to some extent from country to country. In some countries, including Britain, the United States and Germany, the industry is subject to general anti-monopoly legislation. In a number of countries, including the United States, France and Germany, the Government informally influences steel price policy. But it is in the United Kingdom, states the report, that the public supervision and control of the steel industry is most explicitly and effectively " anchored in Statute law." The chosen instrument is the Iron and Steel Board which includes a majority of steel consumers and trade unionists, the steel companies themselves being represented by only two part-time members. The Board has extensive powers of control over steel prices and development as well as more general supervisory duties in respect of all other matters of public interest. This sytem of public supervision, adds the report, is " happily married " to the private ownership and management of individual companies and the collective provision of common services through the industry's trade associations.

The European Coal and Steel Community and the European Free Trade Area which is now being negotiated have opened perspectives of widening international competition in steel, the report states, and without displacing systems of public supervision they are paving the way to intensified control by the consumer through the market.

Science Hall at the Brussels Exhibition

ONE of the principal aspects of modern civilisation, the enormous growth both in scope and importance which the physical sciences have undergone in the course of the last half-century, finds its illustration in the bewildering multiplicity of exhibits of the International Science Hall at the Brussels Universal Exhibition.

This exhibition of scientific achievement occupies 10,700 square feet of Hall VI at the Heysel exhibition grounds. In addition there is a main cinema seating 600 in which a film is being continuously shown dealing with the phenomena of matter up to those of life itself, with special emphasis upon the topic of nuclear fission and fusion. Three small rooms, each capable of seating about 100 people, have also been equipped for cinematograph projection, and are being used for the showing of short films on various matters which could not be included in the main film. One of these rooms is set up as an auditorium where scientific lectures with demonstrations and experiments are being held.

The science exhibition is a co-operative effort by many nations, underlining the basically supranational character of science. On the board of management and the various advisory committees upon whom the organisation of the exhibition devolved, the following countries are represented: The Netherlands, the United States of America, Great Britain, Yugoslavia, France, Austria, Israel, Portugal, Czechoslovakia, Italy, Switzerland, Germany, Spain, the U.S.S.R., and Belgium. The executive committees are Belgian.

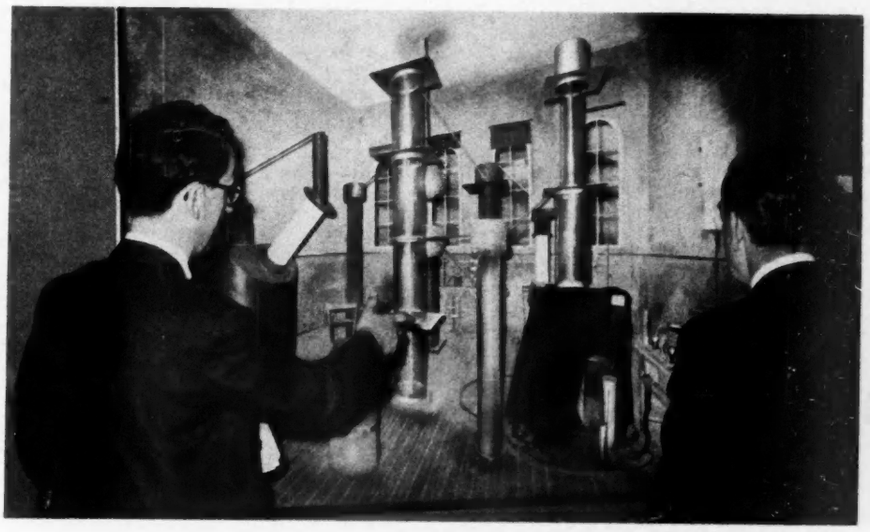
One of the principal problems facing the organisers has been to devise a principle according to which the superabundant material might be grouped and arranged in some sort of system. Eventually, it was decided to confine the exhibition to depicting the progress made during the last fifty years in four principal fields: "the atom"—nuclear and atomic physics; "the molecule"—general and physical chemistry, mineral and organic chemistry; "crystallography," or solid state physics, the study of the structure of matter and the arrangement of molecules and atoms to form the solid state; and lastly, "the living cell,"—the field of plant and animal cytology where some of the chief current problems of cell biochemistry, nerve physiology, plant physiology, and other topics, are examined.

Along one side of the vast hall, a popular section shows these same four basic themes, and demonstrations and experiments are conducted to enable the layman to gain an understanding of the underlying basic science.

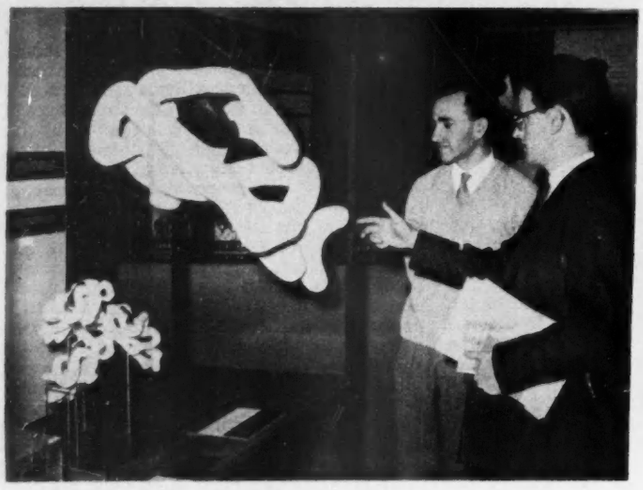
The exhibition is confined to fundamentals; specific applications are shown by the respective countries in their own national pavilions. Thus, the British contribution to what may be called "applied science"—although the distinction between "pure" and "applied" often seems highly artificial—forms one of the most fascinating aspects of the British Government Pavilion, and is further illustrated by many of the things to be seen in the Pavilion of British Industry. Penicillin, jet propulsion, nuclear power, radar and radio-astronomy are some of the fields in which Britain is among the world leaders. Progress towards the harnessing of nuclear fusion is illustrated by a 7ft high (one-third full scale) model of the "Zeta" apparatus at Harwell, with which a year ago the release of neutrons was observed. Other "practical" results of science represented in the British Government Pavilion include a model of the Jodrell Bank radio-telescope with its enormous steerable bowl that can be directed towards any part of the heavens. Another important radio-astronomical piece of equipment is the Mullard interferometer at Cambridge, also shown in model form. The pioneering research done in Britain on nucleic acids is described. These acids are the principal constituents of the nuclei of living cells. Within the nucleus the acids are further concentrated within smaller particles, the chromosomes, the carriers of heredity. Thus the structure and resulting properties of desoxyribonucleic acid form one of the keys to a scientific explanation of heredity and of evolution. In one of the Exhibition's most exciting displays a mechanism is described by which this very complex substance may reproduce itself from much simpler protein elements. Among other scientific exhibits are research on Vitamin B12, the anti-pernicious-anæmia vitamin; the Shirley loom, with greatly improved performance; the Melrose heart and lung machine which has enabled surgeons to reach the heart more easily; the use of giant drainage ploughs in the afforestation of marginal land; new kinds of dyes; a new method of milk preservation by ultrasonic irradiation and deep freezing; and improved techniques for the artificial insemination of cattle.

In order to help the visitor to the International Science to find his way about the four main sections, the Committee have issued a detailed catalogue giving an introductory outline of each field and a sketched description of each exhibit. These descriptions had, of necessity, to be kept to minimum length, or else the size of the booklet would no doubt quickly have been expanded into a scientific encyclopedia. This fact, however, must remain a matter of regret, especially to the layman, who in many cases, perhaps in a majority of instances, finds, on referring from a puzzling exhibit to his guide that he is in no way enlightened either with respect to the nature of the phenomenon under demonstration, its relation to other scientific facts, or its importance to theory. Although it is possible to seek information from the scientists in attendance, this cannot really make up for the deficiencies of the guide. In one respect, however, the guide is of distinct assistance to the non-specialist visitor and that is by its "Introductions" to each of the principal classes of exhibits. These introductions—again, perhaps all-too-briefly—outline the development of the various fields and their place on the sprawling map of modern science, as well as the themes which the organisers of each section set themselves to illustrate.

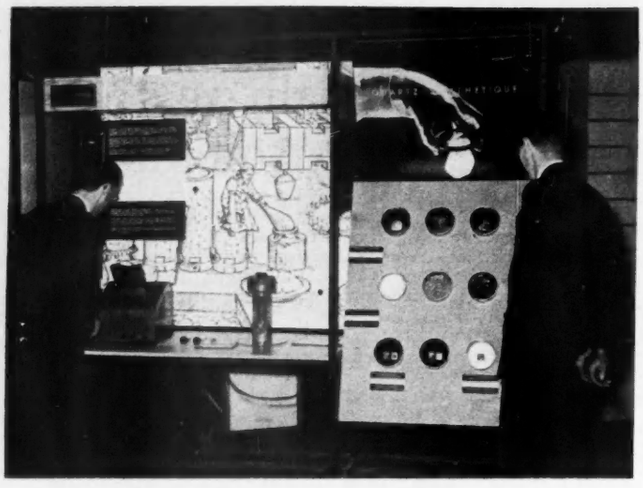
In his "Introduction to the International Science Hall," Sir W. Lawrence Bragg says that although questions as to the "usefulness" of any particular discovery in "pure" science cannot be answered at the time, it could be shown in the case of all important practical advances how they were rooted in fundamental science. In any case, like an explorer, the scientist could not stop to consider questions of utility, or else his progress would be painfully slowed down. Professor Gueben (Liège), speaking of atomic theory, outlines its progress from the ideas of the ancient Greeks to the discovery of the neutrino and the anti-particles in recent months, and surveys the research in radioactivity and cosmic radiation. Introducing the "Crystal" Section, Professor de Keyser (Ghent) gives an elementary account of crystallography, and the application of X-rays to this field. The main object of the "Molecule" Exhibition, according to Professor Smets (Louvain), is to show that molecular structures are based on the same fundamental principles whether they are a simple hydrogen molecule or among the most complex substances, the proteins; that the laws ruling the transformation of matter are general, from the most elementary reactions to the most complex ones; and, finally, to illustrate the methods presently used for the study of structures and of transformations. One of the major scientific revolutions of our time has been the development of our notions on the nature of life. Professor Bordet (Brussels), writing about the section "The Living Cell," tells of the great strides made since the days of Pasteur, largely as a result of our study of viruses (the existence of which in connection with rabies was a hypothesis of Pasteur's). Virus have been obtained in the pure crystalline state and have turned out to be nucleo-proteins, in other words, of the same class of substance as the genes which control the development of an organism. The complexity of such giant molecules (their molecular weights are of the order of tens of millions times that of hydrogen) is naturally very great. Nevertheless, X-ray diffraction has succeeded in some cases in elucidating the architecture of such substances, and experiments have been carried out in which the virulent molecule was first dissociated and then built up again out of the inert component elements thus obtained. Other fields which engage the attention of scientists are those of photo-synthesis, permitting green plants to draw from the sunlight the energy required for the building-up of their bodies; the subtle chemical processes involved in nutrition, on which some light has been shed recently with the aid of electron microscope studies; the chemistry of heredity already mentioned in connection with the British exhibition; embryonic development, and problems of parasitism. This short list describes, by no means exhaustively, the range of the biological section, which is by far the largest as far as the number of its exhibits (206) is concerned, compared with 89, 117, and 98 for



A model of the laboratory in Cambridge where Cockcroft and Walton, in 1932, first split the atom



This exhibit shows the structure of myoglobin, a protein closely related to haemoglobin, recently determined at the Cavendish Laboratory, Cambridge



An exhibit which illustrates the growth of synthetic quartz crystals used in generation of very stable radio frequencies

the "Atom," "Crystal" and "Molecule" sections, respectively.

The Atom

On entering the science exhibition, the visitor faces a large periodic table according to Mendeléyev, flanked with Bohr models of the atoms of hydrogen, helium, lithium, magnesium and sodium, and displays showing the atom to consist of a diminutive but heavy central nucleus, surrounded at a relatively very large distance by planetary electrons. The beginnings of modern atomic science are indicated by stands showing Becquerel's discovery of radioactivity and the work of the Curies. This is followed by the principal instruments of research—counters and cloud and bubble chambers—the various elementary atomic particles, and cosmic radiation. Nuclear fission is demonstrated in two set-ups, one showing the neutron-producing chain reaction in a uranium-water matrix and the principle of control by means of the absorption of neutrons by rods of cadmium; the other is a small research reactor whose core consists of enriched uranium embedded in polyethylene and immersed in water in a concrete tank. Output is 1W (3×10^7 neutrons per cm^2 per second).

A model of the Cockcroft-Walton laboratory at Cambridge is shown in the next section. It was in this laboratory that Cockcroft and Walton succeeded in 1932 in carrying out an artificial nuclear transformation. Other displays show the working principle of the cyclotron and of the linear accelerator. Models are also on view of the CERN 600 MeV synchro-cyclotron and 25 GeV proton synchrotron, as well as of smaller machines such as a 35 MeV betatron, Van de Graaff accelerator, tandem accelerator (Harwell), and high voltage cascade generators from Greinacher's pioneer design of 1921, to a modern 4MV version.

The bewildering variety of "elementary" particles, of which more are being discovered almost every year, is illustrated in the next section which deals with this aspect of nuclear research. Among the rarities of this domain which receive attention are the neutrino (here shown reacting with a proton) and the anti-proton (the exhibit showing its annihilation in collision with a nucleon, with emission of pions, and the impact between an anti-proton and a nucleus). It may be recalled that anti-particles, such as negatively charged particles of the same mass as the proton, and neutrons of opposite magnetic polarity, were first produced artificially at the University of California by means of ultra-high energy accelerators.

Nuclear energy from fusion processes is available on the earth in the form of solar radiation and the section also deals with a variety of proposals for the direct harnessing of this kind of energy, as well as the attempts to bring about a controlled fusion reaction.

The Crystal

Here we are introduced to the properties of crystals and the fundamental laws of crystallography. Many exhibits deal with X-ray diffraction, the tool *par excellence* of modern crystallographic research. Lattice imperfections and their resultant phenomena are demonstrated in several instances, while one stand shows the manufacture of artificial diamonds and of "Borazon," together with actual samples of these substances. Aluminium and its alloys, ferrites, germanium and silicon rectifiers and transistors, the principles of photography, and permanent magnets, are but a few of the topics which are illustrated. Some striking successes in determining the structure of complicated biochemical substances are exhibited. One concerns collagen, a principal constituent of connective tissue which occurs in the form of fibres about one-hundredth millimetre in diameter which, in turn, are built up from bundles of fibrils, and these again from protofibrils. The latter are arranged in a regular fashion, akin to the molecules of a crystal. X-ray analysis has demonstrated that protofibrils are rope-like structures consisting each of three strands of amino-acids of great tensile strength. Another study concerns desoxyribonucleic acid (D.N.A.) to which reference has already been made. An important step forward was the elucidation of the structure of myoglobine, the only protein where this has been possible so far: this substance influences the oxygen economy in muscle.

Crystal growth is illustrated by the production of artificial monocrystals of quartz of great purity, the manufacture of single germanium crystals, and the growth of snow and ice crystals. By means of interference colours it is possible to observe the formation of new layers during the growth of a crystal. Dislocations, changes of phase and the effects of irradiation and mechanical and electrical properties, are further topics which lend themselves to interesting representations by means of models, diagrams or demonstration experiments. Some very beautiful demonstrations are shown in connection with luminescence, fluorescence and phosphorescence.

The Molecule

The study of the molecule is undertaken from several different angles by physical and general chemists. The principal sub-sections represented are concerned with techniques of separation, reaction kinetics, and catalysis, magnetic substances, spectrography, antibiotics, general and macromolecular chemistry, and radiochemistry. Some of the general exhibits at the entrance to the section explain the nature of the different kinds of chemical bond and the energy states of which molecules are capable (Brownian movement, rotations), as well as intra-molecular movements of the constituent electrons which give rise to the various types of spectra, luminescence and kindred effects, and to magnetic phenomena. Some of the most recent advances concern the science of macromolecules which is well represented in the exhibition.

The Living Cell

Here perhaps more than anywhere else, the organisers must have found themselves faced by an *embarrassement de richesse* which necessitated an expansion of the section until it attained in the number of exhibits something like 40 per cent of the total. Its subsections comprise "the chemical constituents of the Cell," genetics, radiobiology, viruses, bacteriophages and bacteria, protozoa and fungi, photosynthesis and the plant cell, the animal cell, and a section on embryology.

Although the mass of the biosphere is insignificant compared with the mass of the atmosphere, which is 300 times, and that of the oceans, which is 69,100 times greater, it is the seat of considerable chemical (i.e. metabolical) activity, estimated to amount to 20,000 million tons per annum on the continents and 126,000 million tons in the oceans. In other words, in 500 million years metabolism on this scale would transform a mass equal to the total mass of the earth. Characteristic is the general unity underlying the processes of life in whatever outward forms they may occur. The exhibition affords a fascinating insight into the research effort which has been and is being made all over the world, which has already led to a deepened understanding of the nature of life, involving in many respects a revaluation of our basic concepts in the biological sphere.

Goransson Centenary

An important milestone in the history of steel, the centenary of the first successful adaptation of the Bessemer process for commercial use by Göran Fredrik Göransson, was the subject of recent celebrations in Sweden. The principal ceremony took place at the Sandvikens Jernverk (Sandviken Steel Works), in Central Sweden, an enterprise originally founded with the aim of exploiting the results of steel-making experiments at the nearby Edsken blast-furnace plant. In honour of the event the 200-year-old Swedish Ironmasters' Association coined a special gold medal.

The industrial adaptation of the Bessemer process was achieved by G. F. Göransson at the small blast-furnace plant of Edsken in July, 1858. From that time onwards Göransson could manufacture continuously an acceptable Bessemer product. At that period the British exploiters of the patents were still subjected to much disappointment and had even begun to lose faith in the method, when the Swedish success gave a new impetus to the experiments. Very soon Bessemer's method began its victorious progress all over the world. Göransson's success was due not only to his courage, tenacity and enthusiasm, but also to the availability in Sweden of many kinds of high-grade ores. He and his collaborators found that sulphurous ores were unsuitable, that a slight manganese content was beneficial for the softer types of steel and that the air-blowing process gave hotter and quicker steel when the tuyeres had become worn. After systematic experimentation with the various methods of furnace design, changes in the technique of tapping, and so on, the Edsken explorers finally arrived at a point where they had the

Bessemer method under full control. After a few years Göransson founded Sandviken in order better to exploit the Bessemer method.

In connection with the Bessemer celebration Sandviken announced the launching of an ambitious investment programme. Investments in the Swedish enterprises in the amount of Kr.30,000,000 (£2,000,000) are being planned, a factory in Birmingham is under construction, and one in Brazil has just been completed. Furthermore, vast projects for capital investments in Asia are under discussion. The Swedish extensions include the addition of two high-frequency furnaces and new equipment for making steel conveyor belts 1200mm wide, the present maximum being 800mm. The Birmingham plant is to produce " Coromant " brand carbide ools, while the Brazilian factory will specialise in carbide-tipped, rock-drill steels.

British-Swedish Chamber of Commerce

The Fourth Annual General Meeting of the British–Swedish Chamber of Commerce in Sweden will take place in Stockholm on September 18. During the past year the Chamber has continued to expand its activities and membership. The total number of members increased during the year from 736 to 872, of which 39 per cent constituted British members. The programme of the meeting includes a review of nuclear energy achievements and applications in the United Kingdom and Sweden. The principal British speaker will be Sir Claude D. Gibb, K.B.E., D.Sc., F.R.S., Chairman and Managing Director of C. A. Parsons and Co., Ltd., and of The Nuclear Power Plant Company, Ltd. His talk will be followed by the new colour film of the Bradwell nuclear power station. On the Swedish side, Mr. Harry Brynielsson, Managing Director of AB Atomenergi, will review the Swedish atomic energy programme and Sweden's import requirements in this connection. His talk will be illustrated by slides on nuclear energy developments in Sweden.

International Conference on Information Processing

An International Conference on Information Processing will be held in Paris from June 15 to 20, 1959. The conference is being organised by the United Nations Educational, Scientific and Cultural Organization (U.N.E.S.C.O.) with the help of a group of consultants from various countries. The programme of the conference will comprise six main headings : methods of digital computing (including numerical analysis); logical design of digital computers ; common symbolic language for digital computers ; automatic translation of languages ; collection, storage and recovery of information ; patterns recognition and machine learning.

An international exhibition of data processing equipment will be held in Paris at the time of the conference, and it is expected that the main manufacturers will be represented. Visits will also be organised to various factories manufacturing such equipment in the Paris area and to computation laboratories in France and possibly in neighbouring countries. Symposia on special subjects (to be announced later) will be held during the conference. It is envisaged that a total of sixty-six papers will be discussed in the course of eleven sessions of three hours each. Persons who wish to offer a paper should send the title, with three copies of an abstract of about 250 words, to their national group before October 1, 1958. Abstracts must be submitted in English or in French (or be accompanied by a translation in one of these languages).

After a preliminary selection, in October, all authors whose abstracts have been selected will be requested to submit the full text of their paper for the final selection. Instructions concerning the presentation of the papers will be supplied at the same time.

Each paper accepted for discussion at the conference will be preprinted in either English or French, and copies will be supplied free of charge, before the conference, to all participants whose registration has been received in time.

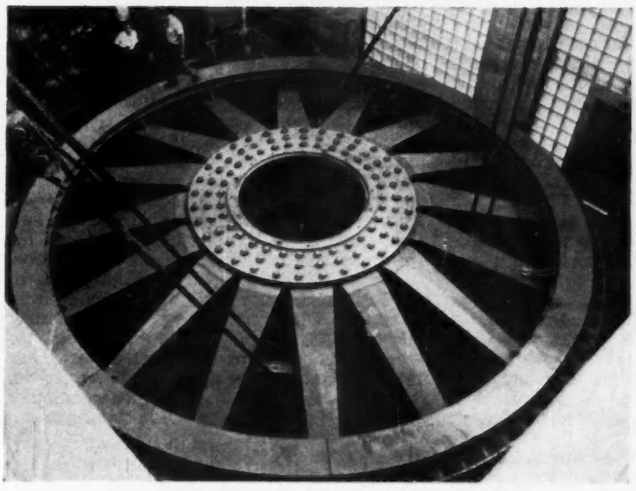
Applications for attending the conference and inquiries must be sent to the competent national groups who will forward them to U.N.E.S.C.O., or directly to the U.N.E.S.C.O. Secretariat, c/o Information Processing Conference, Department of Natural Sciences, Paris, in the case of countries without a national group.

Persons in the United Kingdom wishing to submit papers, or to obtain information, should contact the Honorary Secretary, Group B—Computation and Automatic Control, British Conference on Automation and Computation, c/o The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

First Generator at Ybbs-Persenbeug North

Following the putting into operation last year of the southern section of the Danube power station Ybbs-Persenbeug (see THE ENGINEER, July 20, 1956, page 100, and January 4, 1957, page 33), substantial progress is being made towards the completion of the north station. It will be recalled that the total installed capacity will consist of six sets, three in each station, of 32MW each. Output in the mean year will be 1256 million kWh, of which 43·2 per cent will be in the winter months.

After approximately six weeks' work the first generator spider for the north station has been assembled. The components were delivered by the maker, the Weiz factory of Elin A.G. Because of the large size of this component and its weight, it was not possible to assemble this item at the works and transport it to the site.



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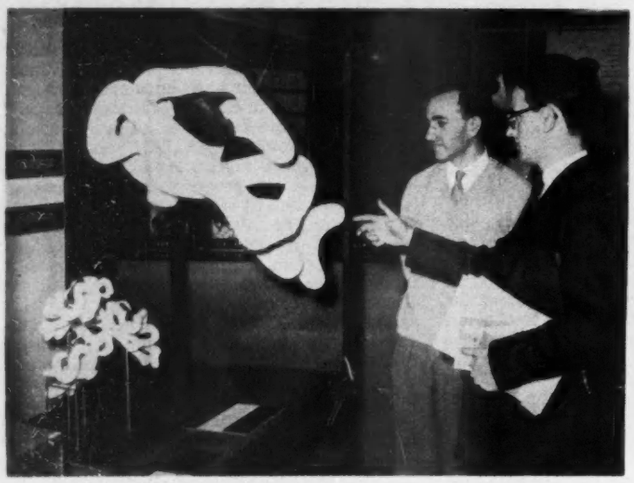
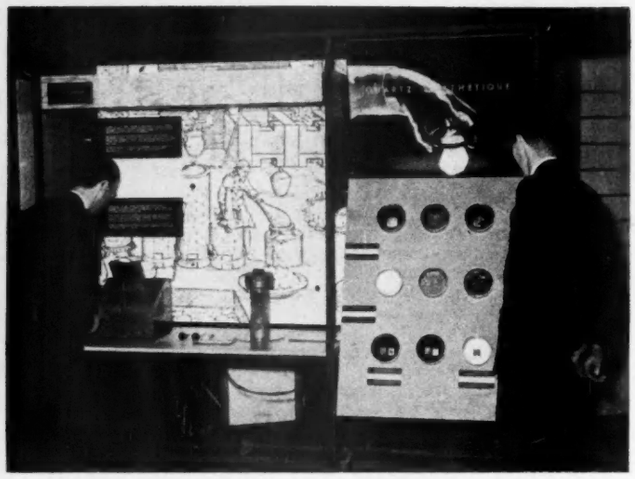


This exhibit shows the structure of myoglobin, a protein closely related to haemoglobin, recently determined at the Cavendish Laboratory, Cambridge



An exhibit which illustrates the growth of synthetic quartz crystals used in generation of very stable radio frequencies

the "Atom," "Crystal" and "Molecule" sections, respectively.

The Atom

On entering the science exhibition, the visitor faces a large periodic table according to Mendeléyev, flanked with Bohr models of the atoms of hydrogen, helium, lithium, magnesium and sodium, and displays showing the atom to consist of a diminutive but heavy central nucleus, surrounded at a relatively very large distance by planetary electrons. The beginnings of modern atomic science are indicated by stands showing Becquerel's discovery of radioactivity and the work of the Curies. This is followed by the principal instruments of research—counters and cloud and bubble chambers—the various elementary atomic particles, and cosmic radiation. Nuclear fission is demonstrated in two set-ups, one showing the neutron-producing chain reaction in a uranium-water matrix and the principle of control by means of the absorption of neutrons by rods of cadmium; the other is a small research reactor whose core consists of enriched uranium embedded in polyethylene and immersed in water in a concrete tank. Output is 1W (3×10^7 neutrons per cm^2 per second).

A model of the Cockcroft-Walton laboratory at Cambridge is shown in the next section. It was in this laboratory that Cockcroft and Walton succeeded in 1932 in carrying out an artificial nuclear transformation. Other displays show the working principle of the cyclotron and of the linear accelerator. Models are also on view of the CERN 600 MeV synchro-cyclotron and 25 GeV proton synchrotron, as well as of smaller machines such as a 35 MeV betatron, Van de Graaff accelerator, tandem accelerator (Harwell), and high voltage cascade generators from Greinacher's pioneer design of 1921, to a modern 4MV version.

The bewildering variety of "elementary" particles, of which more are being discovered almost every year, is illustrated in the next section which deals with this aspect of nuclear research. Among the rarities of this domain which receive attention are the neutrino (here shown reacting with a proton) and the anti-proton (the exhibit showing its annihilation in collision with a nucleon, with emission of pions, and the impact between an anti-proton and a nucleus). It may be recalled that anti-particles, such as negatively charged particles of the same mass as the proton, and neutrons of opposite magnetic polarity, were first produced artificially at the University of California by means of ultra-high energy accelerators.

Nuclear energy from fusion processes is available on the earth in the form of solar radiation and the section also deals with a variety of proposals for the direct harnessing of this kind of energy, as well as the attempts to bring about a controlled fusion reaction.

The Crystal

Here we are introduced to the properties of crystals and the fundamental laws of crystallography. Many exhibits deal with X-ray diffraction, the tool *par excellence* of modern crystallographic research. Lattice imperfections and the resultant phenomena are demonstrated in several instances, while one stand shows the manufacture of artificial diamonds and of "Borazon," together with actual samples of these substances. Aluminium and its alloys, ferrites, germanium and silicon rectifiers and transistors, the principles of photography, and permanent magnets, are but a few of the topics which are illustrated. Some striking successes in determining the structure of complicated biochemical substances are exhibited. One concerns collagen, a principal constituent of connective tissue which occurs in the form of fibres about one-hundredth millimetre in diameter which, in turn, are built up from bundles of fibrils, and these again from protofibrils. The latter are arranged in a regular fashion, akin to the molecules of a crystal. X-ray analysis has demonstrated that protofibrils are rope-like structures consisting each of three strands of amino-acids of great tensile strength. Another study concerns desoxyribonucleic acid (D.N.A.) to which reference has already been made. An important step forward was the elucidation of the structure of myoglobine, the only protein where this has been possible so far: this substance influences the oxygen economy in muscle.

Crystal growth is illustrated by the production of artificial monocrystals of quartz of great purity, the manufacture of single germanium crystals, and the growth of snow and ice crystals. By means of interference colours it is possible to observe the formation of new layers during the growth of a crystal. Dislocations, changes of phase and the effects of irradiation and mechanical and electrical properties, are further topics which lend themselves to interesting representations by means of models, diagrams or demonstration experiments. Some very beautiful demonstrations are shown in connection with luminescence, fluorescence and phosphorescence.

The Molecule

The study of the molecule is undertaken from several different angles by physical and general chemists. The principal sub-sections represented are concerned with techniques of separation, reaction kinetics, and catalysis, magnetic substances, spectrography, antibiotics, general and macromolecular chemistry, and radiochemistry. Some of the general exhibits at the entrance to the section explain the nature of the different kinds of chemical bond and the energy states of which molecules are capable (Brownian movement, rotations), as well as intra-molecular movements of the constituent electrons which give rise to the various types of spectra, luminescence and kindred effects, and to magnetic phenomena. Some of the most recent advances concern the science of macromolecules which is well represented in the exhibition.

The Living Cell

Here perhaps more than anywhere else, the organisers must have found themselves faced by an *embarrassement de richesse* which necessitated an expansion of the section until it attained in the number of exhibits something like 40 per cent of the total. Its subsections comprise "the chemical constituents of the Cell," genetics, radiobiology, viruses, bacteriophages and bacteria, protozoa and fungi, photosynthesis and the plant cell, the animal cell, and a section on embryology.

Although the mass of the biosphere is insignificant compared with the mass of the atmosphere, which is 300 times, and that of the oceans, which is 69,100 times greater, it is the seat of considerable chemical (i.e. metabolical) activity, estimated to amount to 20,000 million tons per annum on the continents and 126,000 million tons in the oceans. In other words, in 500 million years metabolism on this scale would transform a mass equal to the total mass of the earth. Characteristic is the general unity underlying the processes of life in whatever outward forms they may occur. The exhibition affords a fascinating insight into the research effort which has been and is being made all over the world, which has already led to a deepened understanding of the nature of life, involving in many respects a revaluation of our basic concepts in the biological sphere.

Goransson Centenary

An important milestone in the history of steel, the centenary of the first successful adaptation of the Bessemer process for commercial use by Göran Fredrik Göransson, was the subject of recent celebrations in Sweden. The principal ceremony took place at the Sandvikens Jernverk (Sandviken Steel Works), in Central Sweden, an enterprise originally founded with the aim of exploiting the results of steel-making experiments at the nearby Edsken blast-furnace plant. In honour of the event the 200-year-old Swedish Ironmasters' Association coined a special gold medal.

The industrial adaptation of the Bessemer process was achieved by G. F. Göransson at the small blast-furnace plant of Edsken in July, 1858. From that time onwards Göransson could manufacture continuously an acceptable Bessemer product. At that period the British exploiters of the patents were still subjected to much disappointment and had even begun to lose faith in the method, when the Swedish success gave a new impetus to the experiments. Very soon Bessemer's method began its victorious progress all over the world. Göransson's success was due not only to his courage, tenacity and enthusiasm, but also to the availability in Sweden of many kinds of high-grade ores. He and his collaborators found that sulphurous ores were unsuitable, that a slight manganese content was beneficial for the softer types of steel and that the air-blowing process gave hotter and quicker steel when the tuyeres had become worn. After systematic experimentation with the various methods of furnace design, changes in the technique of tapping, and so on, the Edsken explorers finally arrived at a point where they had the

Bessemer method under full control. After a few years Göransson founded Sandviken in order better to exploit the Bessemer method.

In connection with the Bessemer celebration Sandviken announced the launching of an ambitious investment programme. Investments in the Swedish enterprises in the amount of Kr.30,000,000 (£2,000,000) are being planned, a factory in Birmingham is under construction, and one in Brazil has just been completed. Furthermore, vast projects for capital investments in Asia are under discussion. The Swedish extensions include the addition of two high-frequency furnaces and new equipment for making steel conveyor belts 1200mm wide, the present maximum being 800mm. The Birmingham plant is to produce " Coromant " brand carbide tools, while the Brazilian factory will specialise in carbide-tipped, rock-drill steels.

British-Swedish Chamber of Commerce

The Fourth Annual General Meeting of the British-Swedish Chamber of Commerce in Sweden will take place in Stockholm on September 18. During the past year the Chamber has continued to expand its activities and membership. The total number of members increased during the year from 736 to 872, of which 39 per cent constituted British members. The programme of the meeting includes a review of nuclear energy achievements and applications in the United Kingdom and Sweden. The principal British speaker will be Sir Claude D. Gibb, K.B.E., D.Sc., F.R.S., Chairman and Managing Director of C. A. Parsons and Co., Ltd., and of The Nuclear Power Plant Company, Ltd. His talk will be followed by the new colour film of the Bradwell nuclear power station. On the Swedish side, Mr. Harry Brynielsson, Managing Director of AB Atomenergi, will review the Swedish atomic energy programme and Sweden's import requirements in this connection. His talk will be illustrated by slides on nuclear energy developments in Sweden.

International Conference on Information Processing

An International Conference on Information Processing will be held in Paris from June 15 to 20, 1959. The conference is being organised by the United Nations Educational, Scientific and Cultural Organization (U.N.E.S.C.O.) with the help of a group of consultants from various countries. The programme of the conference will comprise six main headings : methods of digital computing (including numerical analysis); logical design of digital computers ; common symbolic language for digital computers ; automatic translation of languages ; collection, storage and recovery of information ; patterns recognition and machine learning.

An international exhibition of data processing equipment will be held in Paris at the time of the conference, and it is expected that the main manufacturers will be represented. Visits will also be organised to various factories manufacturing such equipment in the Paris area and to computation laboratories in France and possibly in neighbouring countries. Symposia on special subjects (to be announced later) will be held during the conference. It is envisaged that a total of sixty-six papers will be discussed in the course of eleven sessions of three hours each. Persons who wish to offer a paper should send the title, with three copies of an abstract of about 250 words, to their national group before October 1, 1958. Abstracts must be submitted in English or in French (or be accompanied by a translation in one of these languages).

After a preliminary selection, in October, all authors whose abstracts have been selected will be requested to submit the full text of their paper for the final selection. Instructions concerning the presentation of the papers will be supplied at the same time.

Each paper accepted for discussion at the conference will be preprinted in either English or French, and copies will be supplied free of charge, before the conference, to all participants whose registration has been received in time.

Applications for attending the conference and inquiries must be sent to the competent national groups who will forward them to U.N.E.S.C.O., or directly to the U.N.E.S.C.O. Secretariat, c/o Information Processing Conference, Department of Natural Sciences, Paris, in the case of countries without a national group.

Persons in the United Kingdom wishing to submit papers, or to obtain information, should contact the Honorary Secretary, Group B—Computation and Automatic Control, British Conference on Automation and Computation, c/o The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

First Generator at Ybbs-Persenbeug North

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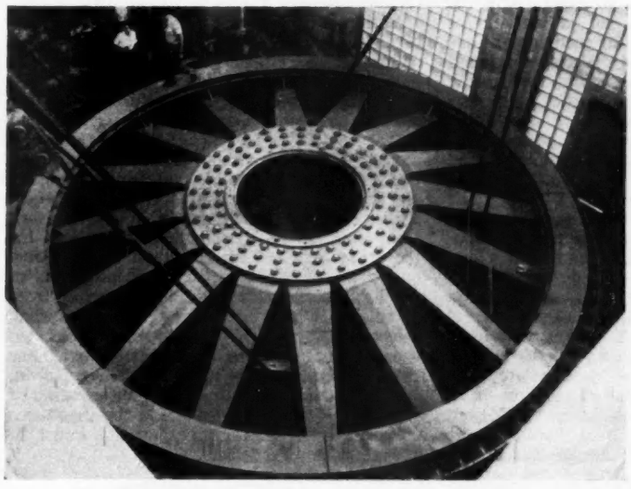

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High-Temperature Research at the National Bureau of Standards

BY OUR AMERICAN EDITOR

No. I

Recent developments in high-speed flight, rocket propulsion, and nuclear reactors have raised operational temperatures from well below 1000 deg. Cent. into a range up to 4000 deg. Cent., in which there had been little scientific or industrial experience. Until recently the work on materials done by the National Bureau of Standards was largely confined to the more conventional temperature ranges. However, a high-temperature research programme has grown quickly, mainly as a result of the Bureau's efforts to meet its assigned responsibility for devising precise measurement methods and determination of the basic properties of materials. The high-temperature research programme may be divided into three groups : (1) Studies of structure ; (2) determination of properties and constants of materials ; and (3) development of methods and instrumentation for high-temperature measurements.

As part of an intensified effort at the National Bureau of Standards, Washington, D.C., to learn more about the structure of materials at high temperatures, extensive use is made of such techniques as X-ray and electron diffraction, electron microscopy, and infra-red spectroscopy. Of particular interest for many high-temperature applications are the transformations in structure and properties that occur in materials as the temperature rises. A number of carefully co-ordinated investigations at present deal with changes of this kind. The second general area is concerned, to a very large extent, with the thermodynamic properties of a variety of potentially useful materials for such applications as aircraft fuels, container materials, or heat-transfer media. However, the mechanical, thermal, and chemical properties of high-temperature glasses, refractories, and other structural materials also receive emphasis. In correlating and predicting the behaviour of many high-temperature alloys and ceramics, phase equilibrium studies are playing an important part.

A serious problem in high-temperature research has been the lack of adequate methods and instrumentation not only for producing and measuring high temperatures but also for determining changes in various kinds of materials at these temperatures. For example, special heat-resistant strain gauges, giving reliable results under extreme conditions, are required for measuring mechanical properties. A number of techniques—such as differential thermal analysis, X-ray diffraction, and electric arc discharge—are now being investigated for use in determining high-temperature properties. Considerable work has also been done on furnaces for producing uniform high temperatures, and the temperatures of flames and other hot gases are being studied spectroscopically to provide methods of measuring temperature where conventional techniques cannot be applied.

Thermodynamic Properties of Gases

The quantitative relations between the heat in a gas and the work done by the gas as it expands are important in describing how the gas acts at high temperatures under the extreme conditions encountered, for example, in rocket power plants. An important characteristic of gases in such high-temperature applications is the relative ease with which heat flows through the gases when a temperature difference exists. Since highly energetic flow of gas is rarely of a simple, smooth nature, the ordinary thermal conductivity measurement technique is not sufficient for heat-flow determinations ; information must be obtained on other quantities such as viscosity, and, in the common case of a chemically reacting gas mixture, on rates of material flow due to diffusion.

The Bureau has been able to estimate these transport properties and also the thermodynamic properties for common gases up to quite high temperatures. Because these temperatures extend far above the regions of accurate direct measurement, it has been necessary to compute properties according to fundamental principles of statistical mechanics, using the information available on energies of the internal " quantised " states for the various constituents. From this information, empirical estimates can be made concerning the way in which inter-action energies between individual molecules, free radicals, atoms and ions depend on their instantaneous positions in space relative to each other. When experimental data relevant to related properties at lower temperatures are available, comparison may in some cases supply part of the necessary data upon which estimates of high-temperature properties can be based.

Various aspects of the work on the properties of air have indirect application to estimates of its properties at high temperatures. Measurements below ordinary room temperature include liquid-vapour phase equilibria for oxygen and nitrogen mixtures, heats of vaporisation and surface tension for oxygen and nitrogen and their mixtures, and simultaneous measurements of pressure, specific volume, and temperature for air from room temperature down to 125 deg. Kelvin, shortly to be extended upward toward 1000 deg. Kelvin. Using tabulated values for the constituents of air based on spectroscopic data available, the thermodynamic properties of air have been calculated in the region from 10^4 deg. Kelvin to 5×10^6 deg. Kelvin, omitting molecular formation, for densities from ten times normal down to 10^{-6} times normal. For the more limited region up to 15,000 deg. Kelvin, thermodynamic calculations on the formation of molecules have also been made for argon-free air from 100 times normal density down to 10^{-6} times normal density.

Chemical Reactions

Although a considerable body of experimental and theoretical knowledge has been accumulated about liquid and gas phase reactions at temperatures up to a few hundred degrees, at higher temperatures this field remains largely unexplored. Many such reactions, particularly those between a solid and its gaseous environment (for example, a metal and atmospheric oxygen or nitrogen) involve a change in mass. The rate of such reactions can thus be conveniently determined on small-scale specimens by following the change in weight of the specimen during the reaction.

To study such reactions, the Bureau has constructed a quartz micro-balance operating inside a glass vacuum envelope, together with associated heating and vacuum equipment. The balance can measure weight changes of the order of 0·2 to 0·3 microgramme. On a specimen having a surface area of 5 square centimetres, this would correspond to about one layer of oxygen molecules. The instrument can aid in studying reaction rates at temperatures up to about 1400 deg. Cent. at gas pressures ranging from atmospheric down to 10^{-6} millimetre. It has been designed to determine gas adsorption and the vaporisation behaviour of solids at elevated temperatures.

The microbalance is being used to study the oxidation behaviour of metallic niobium (columbium), a material that oxidises rather rapidly at temperatures higher than 200 deg. to 300 deg. Cent. Its oxidation rate is subject to a number of complexities which make it of theoretical interest. If its tendency towards rapid oxidation could be overcome, it would be of considerable practical interest as a high-temperature structural material because of its high melting point, ease of fabrication at room temperatures, and low neutron capture cross section.

Synthesis of Crystalline Compounds

Closely related to this work is the synthesis of pure inorganic crystalline compounds that can be used to measure precise constants. Most natural compounds or minerals contain varying amounts of impurities which alter their true properties ; however, little is known concerning how these properties change with a given impurity. One of the present objectives is to add controlled amounts of impurities to the synthetic compound and to measure the change in properties as compared to the pure analogue. Synthesis or crystallisation experiments are carried out at high temperatures and pressures, using the techniques of solid state reactions, hydro-thermal reactions, and reactions obtained from a crystallising melt. In a steel bomb with a hollow centre, temperatures up to 1500 deg. Cent. and pressures up to 10,000 atmospheres may be reached (Fig. 1). Pressure is generated by pumping inert gas into the chamber ; the high temperatures are obtained by means of an internal electrical resistance element of platinum or tungsten. The apparatus can also be used to study differential-thermal reactions at elevated pressures. Another apparatus that can attain temperatures up to 1000 deg. Cent. and pressures up to 50,000 atmospheres consists essentially of two opposing tungsten carbide cylinders of ¼in diameter, surrounded by an induction heating coil. The material to be reacted is placed between the two pistons. In this case pressure is obtained from a hydraulic press.

Studies are now in progress on the conditions necessary to synthesise such pure silicates as : (1) beryl or emerald ($2BeO.Al_2O_3.6SiO_2$); (2) the humites (n $Mg_2.SiO_4.MgF_2$) where n=1, 2, 3, and 4, or (3) coesite (SiO_2), a new dense polymorph of quartz. Beryl, which melts incongruently at a temperature of 1425 deg. Cent. at a pressure of 1 atmosphere, can be synthesised hydrothermally or from solid state reactions at temperatures of 850 deg. Cent. and pressures of 20,000 lb per square inch, using formula proportions of the constituent oxides or sulphates. All the reactions take place in sealed platinum containers. Attempts are now in progress to substitute ions in the beryl structure which are known to substitute for similar ions in other structures. For example, it is known that germanium will substitute for silicon in structures such as forsterite (Mg_2SiO_4). It is possible that germanium will substitute for silicon in beryl. If this reaction can be carried out, the properties of the resulting germanium beryl should be quite different from those of silicon beryl.

The humites have been synthesised under variable conditions of high temperature and pressure, and recently a complete substitution of germanium for silicon was achieved in the structure, having the composition of $Mg_2GeO_4.MgF_2$. The optical properties and the density of the material were found to be increased by the substitution. Coesite, a dense polymorph of SiO_2, can be synthesised at 700 deg. Cent. and 30,000 atmospheres. Infra-red transmission techniques have demonstrated that its structural framework (SiO_4 tetrahedra) is the same as that of quartz. The difference in density between quartz and coesite is due primarily to a rearrangement of the SiO_4 tetrahedra and not to any distortion of the individual tetrahedra.

Mechanical Properties of Glasses

Engineering data on a number of representative glasses near the upper limits of their potentially useful temperature range are being obtained by the Bureau with the support of the Wright Air Development Centre and the co-operation of several of the commercial American glass producers. The properties under study are the strength, or modulus of rupture ; the modulus of elasticity ; Poisson's ratio ; stress-rupture,

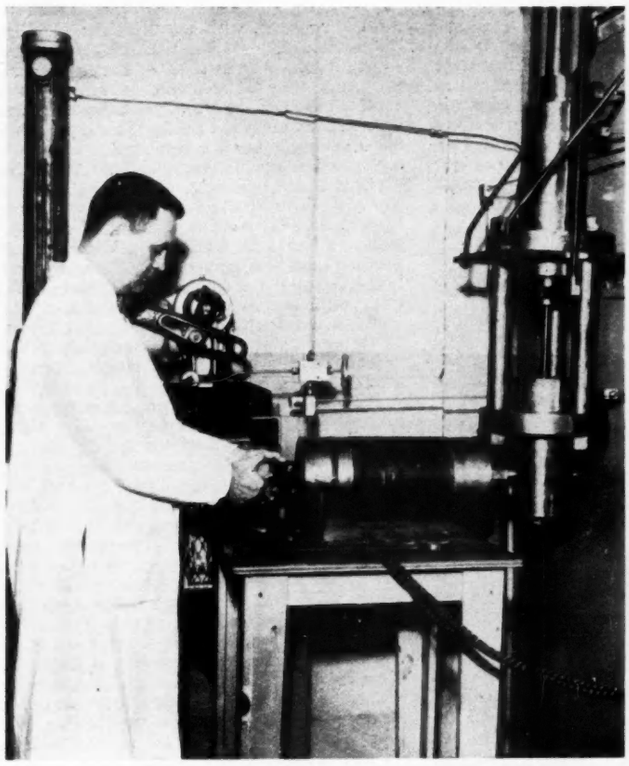


Fig. 1—Steel bomb for crystallisation experiments at temperatures up to 1500 deg. Cent. and pressures up to 10,000 atmospheres

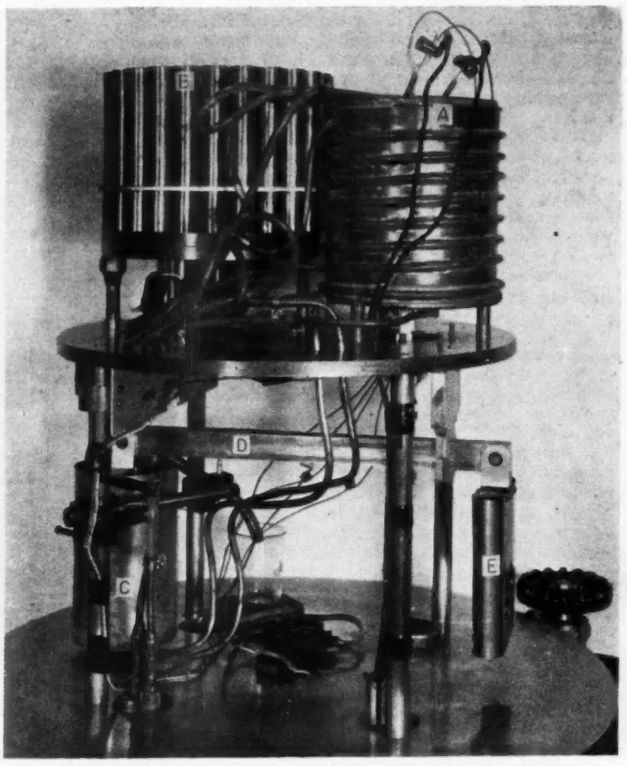


Fig. 2—Apparatus for measuring the flexural strength of uranium and thorium dioxides at temperatures up to 1000 deg. Cent.

or static fatigue ; and creep. The test temperatures range from room temperature to near the strain point of the glass, with 940 deg. Cent. being the highest temperature at present. Glass is tested with both short and long-term exposures up to 500 hours.

The strength of glass is greatly affected by surface conditions, internal strain (including the intentionally introduced strains in " tempered " glass), rate of loading and humidity of the atmosphere. These conditions are systematically varied with the testing temperature and with the heat-treatment before testing. Reliable strength measurements are difficult to obtain on glass even with closely controlled sample preparation and testing conditions. It was found, however, that controlled abrasion of the surface of the samples gave more uniform, but lower, results than were obtained with polished samples. However, the strengths of the weakest samples of each group appeared to be approximately the same. Statistical treatment of the test results has aided in evaluating the effect of the various conditions on strength and in the planning of future tests.

Protective Coatings for Metals and Alloys

Nearly all metals and alloys of practical interest oxidise when heated to high temperature. This oxidation weakens the material and, in some cases, completely prevents the use of certain high-strength metals and alloys for such high-temperature applications as gas turbines and nuclear reactors. The Bureau has been actively engaged in finding ways of reducing this corrosion at high temperatures. One approach is a ceramic coating (Fig. 3). Such coatings are normally applied at a thickness of 0·001in to 0·002in and are bonded to the metal surface by heating the part to high temperatures. Coatings of this general kind have provided extended service life for stainless steel parts. One of the Bureau coatings, NBS A-418, which was developed for the National Advisory Committee for Aeronautics, has found extensive use for the protection of certain components in jet engines. A second Bureau coating was designed specifically for low neutron absorption. This coating can reduce the oxidation of specimens made of an 80 Ni-20 Cr alloy by as much as 60 per cent at 2050 deg. Fah. In addition, lower creep rates were observed for coated specimens under certain test conditions. The coatings were developed for use in nuclear reactors of advanced design.

Cement-like ceramic coatings have also been developed. These coatings, which have the advantage of a low firing temperature, were developed under N.A.C.A. sponsorship. They are intended to provide both short-time thermal insulation and a surface of controlled emittance for missiles and aircraft travelling at supersonic speeds.

Coatings for the refractory metals have also received attention. Ceramic and ceramic-metal compositions have been devised that give good short-time protection to molybdenum at gas temperatures up to 3500 deg. Fah. A second approach is to electroplate layers of such metals as nickel and chromium on the molybdenum surface. A thin layer of chromium is applied first ; nickel is then deposited at a thickness of approximately 0·009in. Protection of the molybdenum for periods up to 1000 hours at 1000 deg. Cent. has been achieved with layers of this type.

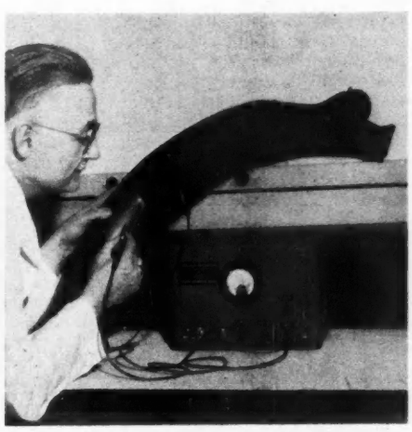


Fig. 3—Test of an experimental ceramic coating

Radiation Properties of Materials

Under the sponsorship of the National Advisory Committee for Aeronautics and the U.S. Army Ballistics Missile Agency, the Bureau is studying the high-temperature radiation characteristics of enamelled coatings for metals. Measurements are being made by comparing, for a great number of wavelengths, the energy emitted from coated metals to the energy emitted by a laboratory black-body furnace at the same temperature.

Aircraft or missiles operating at hypersonic speeds within the atmosphere develop high temperatures from skin friction. At these elevated temperatures, undesirable creep or corrosion of structural components can take place. Radiation is an important means of dissipating such heat. As the temperature of a hot body increases above a bright red heat radiation will account for a major portion of the heat flow at atmospheric pressure. At high altitudes, as the density of the atmosphere decreases toward the vanishing point, the relative importance of radiation becomes even greater and ultimately becomes the only means of heat transfer. The amount of heat transferred by radiation is determined through comparison with a black body. An ideal black body is opaque, absorbs all radiant energy incident upon its surface, and emits the maximum possible amount of radiant energy at any temperature. Well-known physical laws give the amount of such radiant energy as a function of temperature, and its spectral and geometric distribution. All known materials depart to some extent from these laws, and the degree of approach to black-body properties is defined as the emittance or, under specified conditions, the emissivity. Emittance is the ratio of the radiant energy emitted by a specimen of material to that emitted by a black body under similar conditions. For most materials it varies with the temperature and with the wavelength over the spectrum of emitted radiation.

For computations of radiant heat transfer, accurate values of the spectral emittance of the hot body, at its temperature, and the spectral absorptance (emittance) of the cold body, and its temperature, are required. The Bureau is now making studies to obtain such data for aircraft and missile structural and coating materials. To evaluate the effectiveness of enamelled coatings

on metals, comparisons must be made against uncoated metals. Curves of spectral emittance of two alloys, Inconel and A.I.S.I. type 321 stainless steel, have been determined over the wavelength range of approximately 1·5 to 15 microns. Specimens were subjected to one of six different treatments before evaluation; (1) electro-polishing; (2) sand-blasting; (3) electro-polishing followed by oxidation in air for thirty minutes; (4) sand-blasting, then oxidation in air for thirty minutes at 1800 deg. Fah.; (5) coating with N.B.S. ceramic coating A-418; or (6) coating with N.B.S. ceramic coating N-143. Measurements were made at 900 deg., 1200 deg., 1500 deg. and 1800 deg. Fah.

Ceramics and Cermets

Ceramics and cermets are being used increasingly where high strength and resistance to erosion and chemical corrosion under extreme conditions of temperature are required. To realise the fullest potentialities of these materials, the Bureau is investigating such mechanical properties as strength and creep throughout the intended range of use, as well as the relationships between these properties and such parameters as grain size, porosity, temperature, minor additions and structure. The strength of brittle polycrystalline materials appears to vary inversely as the grain size and porosity. In the normal maturing process, the grain size usually increases as the porosity decreases. Minor additions to ceramic materials can exert a profound influence on both porosity and grain size and consequently on strength.

The investigation of some of these materials at elevated temperatures requires special equipment or techniques. For example, in the investigation of uranium dioxide or graphite, it is necessary to provide a protective atmosphere to prevent oxidation of the specimens. Also, because of the limited availability of many of the materials of interest, it has been necessary to "miniaturise" much of the testing equipment. The programme in the high temperature region includes measuring the flexural strength of uranium dioxide and thorium dioxide at temperatures

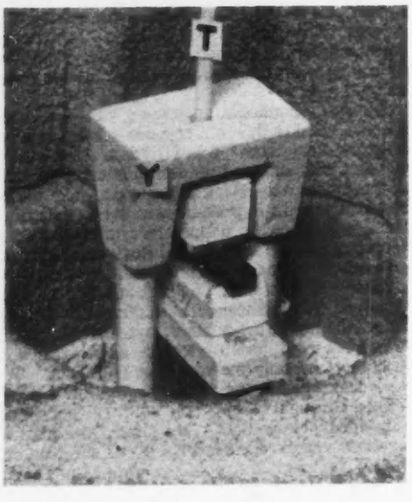


Fig. 4—Interior view of furnace chamber during flexural strength test at high temperature

up to 1000 deg. Cent. (Figs. 2 and 4). In addition, the effect of minor additions on the strength of uranium dioxide at these temperatures has been investigated. The flexural strength of single crystal aluminium oxide has been investigated up to 1200 deg. Cent., and a method developed to determine the minimum stress required to cause creep by means of the flexural strength test. Other properties, such as the modulus of elasticity Poisson's ratio and internal friction are being studied on a variety of materials at temperatures as high as 1600 deg. Cent.

Heat Capacity and Conductivity

Numerous laboratories throughout the country are engaged in measuring the heat capacities and heat conductivities of high-temperature materials. Through its current high-temperature heat measurements programme, the Bureau is contributing to this activity in two important ways. First, materials suitable as standards are chosen, and their heat conductivities and heat capacities are measured accurately. Other laboratories using simpler apparatus or more rapid methods can then use these standards to check their own measurements for constant errors that would otherwise go undetected. An example of a

Fig. 5—Furnace and calorimeter for measuring high-temperature heat capacities of solids or liquids

heat capacity standard resulting from this programme is synthetic sapphire (aluminium oxide), useful up to 900 deg. Cent. This standard is now being extended up to 1500 deg. Cent. During the past few years, it has been widely used for comparisons throughout this country and abroad.

The second contribution is in making measurements on materials of fundamental or critical importance where high-temperature properties need to be known with the highest accuracy (Fig. 5). For example, measurements of both the heat conductivity and the heat capacity of beryllium oxide were recently completed. This solid has one of the highest melting points of non-oxidisable materials known, and is thus an important high-temperature structural material. Its relatively high heat conductivity reduces its susceptibility to thermal shock. Measurements have also been made on the high-temperature heat capacities of fifty important metals, alloys, refractory solids, salts and stable organic compounds. In some cases serious discrepancies among results previously obtained have been corrected. In about two dozen cases the Bureau's results have completed the information needed to calculate accurately the extent to which the materials undergo many of the most common and important chemical and physical changes at high temperatures.

The Heat Division of the N.B.S. recently has developed accurate methods for determining some of the more important thermodynamic properties of the zirconium-hydrogen system from specific heat data. These methods, which can be conveniently applied to many other heterogeneous systems, are expected to be of value in predicting the high-temperature behaviour of a wide variety of materials. They should be particularly useful in determining the properties of systems in which heat exchanges due to chemical reactions between the constituents occur over the temperature range under study.

The hydrides formed when zirconium absorbs large quantities of hydrogen are solid, alloy-like substances, stable to remarkably high temperatures. Together with the hydrides of other transition metals—such as titanium and uranium—they form a unique class of materials whose properties often differ markedly from those of other substances. In recent years there has been an intensified effort to investigate these properties more completely and systematically because of their importance in metallurgical and other problems. For example, the embrittlement of slowly cooled zirconium metal has been shown to be due to the reaction of traces of hydrogen with the metal to form an insoluble hydride phase. Complete data on the thermodynamic properties of the zirconium hydrides would not only permit a more reliable prediction of their chemical behaviour at high temperatures, but would also make possible a clearer theoretical understanding of the forces which determine their structures and properties.

The methods used in the present investigation of thermodynamic properties require highly accurate determination of the specific heats of the samples over the temperature range involved. Data were obtained to the desired accuracy with apparatus developed and refined over a period of years for use in making precise measurements on specific heat standards. The specific heats from 0 deg. to 900 deg. Cent. of zirconium metal and of five samples of zirconium hydride (containing from 0·35 to 1·17 per cent hydrogen by weight) were measured precisely in an ice calorimeter by the "drop" method. In this method the sample, sealed in a container, is suspended in the furnace until it comes to a known constant temperature. It is then dropped into the calorimeter, where it melts ice in equilibrium with water in a closed system. The resulting volume decrease in the ice draws mercury into the system and the mass of mercury moved is proportional to the heat energy lost by the sample (relative heat content) in cooling from its initial temperature to 0 deg. Cent.

The data obtained in this way were then applied to evaluate the limits of composition of the various phases of the zirconium-hydrogen system at temperatures between 0 deg. and 900 deg Cent. Two methods, each based on older techniques, were developed. One method takes advantage of the fact that the energy-composition isotherms show breaks at any phase-diagram boundary separating two phase fields. These breaks in the isotherms can be determined from the sudden increase in specific heat when the sample reaches a temperature where a new phase appears. Thus, the method is actually a refinement of the cooling curve method for obtaining phase compositions. However, it can be used with many all-solid systems that approach equilibrium quite slowly. Here the cooling curve method would be impractical.

The second method determines the limits of phase composition by locating the compositions where the pressure isotherms derived from the specific heat data show breaks. Results agreeing with the first method and with older methods were obtained when it was assumed that the pressure isotherms had shapes which support an earlier conclusion. This conclusion was that when zirconium metal dissolved hydrogen gas the hydrogen molecules were broken up into atoms to form true hydrides. The experimentally obtained specific heats were also used to obtain a measure of the relative energies of the various hydride phases at different temperatures. Whenever a temperature is reached where a new phase appears, the increase in specific heat can be attributed quantitatively to the energy of creating the new phase from the old. Based on this principle, a method was developed which made it possible to calculate the heats of formation of a great number of zirconium hydrides over the whole temperature range, using a single previously known value for one of the hydrides.

Considerable information was obtained regarding the beta zirconium hydrides, which are unstable at lower temperatures and thus cannot be studied readily by room-temperature techniques; at high temperatures their crystal structure is the same as that of zirconium metal. A marked absorption of heat was observed at the eutectoid temperature. This was due to the formation of the beta solution of zirconium and hydrogen from the lower-temperature hydride structures, with the absorption of 2·2 kcal/mole.

These solid beta solutions are analogous to liquid solutions so commonly encountered above their eutectic temperatures, and the unusually high entropies of the beta solutions reflect the liquid-like disorder of the hydrogen atoms in the interstices of the crystalline zirconium lattice. Neutron diffraction data show that when enough hydrogen is added to the beta solutions to approach the composition ZrH_2, a tetragonal lattice is formed. Each unit cell of this lattice has four faces on which hydrogen atoms can be located. No corresponding diffraction data are available to locate the hydrogen in the beta phases, but it is known that the unit cell is cubic instead of tetragonal and thus would provide six equivalent faces on which hydrogen atoms could be located. This concept is supported by the high entropies obtained for these phases. These entropies show, in fact, that the beta phases contain at least 50 per cent more hydrogen sites than do the more ordered tetragonal lattices.

Heat Flow

Two thermal properties of materials must be known to calculate heat flow. One is the thermal conductivity, which is analogous to electrical conductivity. The other property is thermal diffusivity, a measure of heat flow. When a material is at constant temperature, its thermal conductivity is a direct measure of the heat flow through the material having known temperature gradient and dimensions. When the temperature of the material is changing, thermal diffusivity is calculated by dividing the thermal conductivity by the heat capacity per unit volume.

Very accurate measurements have been made of the thermal conductivity of pure nitrogen gas up to 500 deg. Cent. and 100 atmospheres pressure. These measurements serve as standards for other laboratories to calibrate apparatus for use with other gases. Measurements have also been made of the thermal conductivity of a number of solids up to 800 deg. Cent. As a result of the increasing interest in measurements at higher temperatures, apparatus is being developed for extending the measurements to about 1500 deg. Cent. At the higher temperatures, determinations of thermal conductivity become increasingly difficult because they involve both absolute measurements of temperature gradient and of power. On the other hand, determinations of thermal diffusivity do not require these measurements ; instead, they may involve only time interval measurements, which are much easier to make. For this reason, at the higher temperatures, only measurements of diffusivity from which conductivity values can be obtained through knowledge of heat capacities are planned. At the present time diffusivity measurements are being made on iron, since this material has been used as a tentative standard in many laboratories. Future work is expected to include measurements on selected ceramic materials which may also serve as standards.

Standard X-ray Diffraction Patterns

Before high temperature reactions can be understood, the substances must be identified and the structures elucidated. X-ray diffraction provides a method for both identifying compounds and determining structure. The American Society for Testing Materials research fellowship at the Bureau greatly facilitates the identification of materials by constantly reviewing the A.S.T.M. powder patterns and extending the files by preparing new patterns. Studies are also carried out by single crystal techniques. These studies provide the structural information necessary for the complete understanding of any phase changes or reactions at any temperature.

Polymers

An investigation has been undertaken to develop new polymeric materials capable of withstanding very high temperatures. This work is part of a broader programme which seeks to obtain basic data on the relationship between the structure of polymers and their stability. In the course of the investigation, a number of new fluorinated organic and semi-organic compounds have been successfully synthesised. One of these materials has been used to prepare a new polymer, a fully fluorinated polyphenyl, which appears to be very stable to thermal degradation. Preparations are now being made to study the behaviour of various polymers at temperatures as high as 1500 deg. Cent. The polymers will be subjected to flash pyrolysis, and the fragments into which the polymer chain is decomposed by heat will be studied to obtain information for the further development of heat-resistant polymers.

Alloy Steels

The Bureau has undertaken a study for the Wright Air Development Centre to evaluate the effects of variations in heat treatments (including refrigeration) on the mechanical properties of the new American "17-7 PH" (17 per cent Cr —7 per cent Ni, precipitation-hardening) stainless steel, and to determine heat-treatments that will result in optimum mechanical properties at temperatures ranging from 70 deg. to 800 deg. Fah. (Fig. 6). Further objectives are to determine the mechanisms of

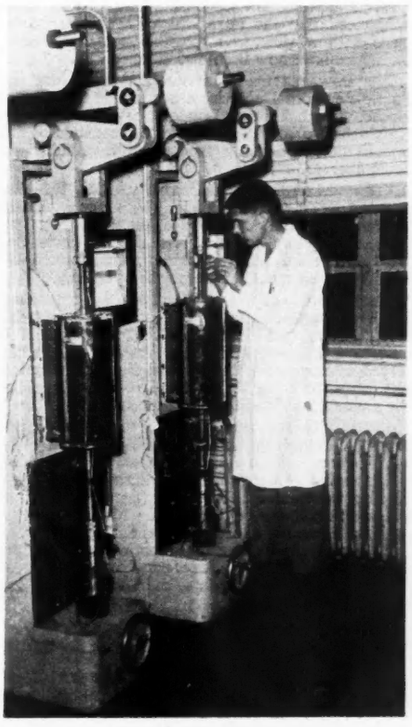


Fig. 6—Creep test machines employed in studying the high-temperature properties of "17-7 PH" stainless steel

hardening, to identify and locate the hardening compounds, to evaluate the effects of nitrogen upon the properties of the steel and to develop methods of eliminating or ameliorating the loss in ductility resulting from prolonged exposure at temperatures below the precipitation-hardening range. Precipitation-hardening stainless steels, such as 17-7 PH, are now being widely used at tensile strength levels of 175,000 lb to 200,000 lb per square inch in aircraft where the components attain moderately elevated temperatures during flight. Up to about 800 deg. Fah., these steels retain about 75 per cent of their room-temperature tensile strengths.

Results of the Bureau's research so far indicate that the 17-7 PH steel can be heat-treated to obtain a tensile strength of 225,000 lb per square inch at room temperature with sufficient ductility to be used in aircraft construction. Optimum heat-treatment results in rupture life of 100 hours at a stress of 175,000 lb per square inch at 600 deg. Fah. or a stress of 115,000 lb per square inch at 800 deg. Fah. X-ray diffraction studies of solution-annealed specimens show the presence of gamma and alpha iron and indicate the possible presence of a solid solution of titanium-carbide and titanium-nitride and a nickel-titanium-aluminium compound in addition to some unidentified constituent or compound.

As the strength of most steels decreases appreciably at elevated temperature, the development of materials having high strength at elevated temperatures becomes increasingly important. The moderately alloyed tool steels known as hot-work die steels may be heat-treated to very high strengths. The alloying elements normally present in these steels tend to minimise the loss in strength that otherwise would occur at temperatures up to 1000 deg. Fah. Because of these characteristics, four commercial 5 per cent chromium hot-work die steels have been selected for study ; their strength properties are being evaluated by means of tensile and stress-rupture tests at temperatures up to 1000 deg. Fah. On the basis of the results obtained, experimental steels of modified analyses will be melted, fabricated, heat-treated and tested in an effort to develop a steel having improved high-temperature strength. The results obtained to date on heat-treated specimens of some of the commercial steels show tensile strengths in excess of 200,000 lb per square inch at 1000 deg. Fah. and sufficient ductility for use in aircraft components.

Stainless Steel Corrosion

Crude oil from some oil fields contains traces of a vandium compound. This compound is not removed during refining of the oil but remains in the residue that is sold as fuel oil for ships, power plants or turbines, and forms vanadium pentoxide, when burned. At temperatures above 1100 deg. Fah., the vanadium pentoxide, together with the sodium compounds always present in oil transported by tanker, forms a slag that will attack many metallic materials including high-alloy stainless steels. This corrosion results in frequent costly replacement of boiler parts. At the request of the U.S. Navy Bureau of Ships, the Bureau is determining the minimum temperature at which the slag attack begins and the fundamental mechanism of attack of the slag on the steel. The temperature has been determined to be 1075 deg. Fah. ; the intensity of attack increases rapidly with increasing temperatures. The mechanism is being investigated.

(*To be continued*)

Sudden Power Increase of Solution Reactor

A NUCLEAR research reactor, known as KEWB, recently increased its power output from zero to 530,000 thermal kilowatts in less than a second After the power increase, the reactor shut itself off without sustaining any damage. This rate of power increase is the largest known to have been experienced safely by a reactor and amounted to tripling the power every two-thousandths of a second. The power surge occurred in a special test to study the behaviour of an aqueous homogeneous reactor if operating control were lost. In this test, KEWB was subjected to severe operating conditions when far more fissionable uranium than required for normal operation was suddenly made available for a chain reaction by the removal of the control rod.

KEWB (Kinetic Experiment on Water Boilers) was designed and built for the U.S. Atomic Energy Commission by Atomics International to conduct reactor safety experiments under scientifically controlled conditions. It is a 50kW aqueous homogeneous research reactor fuelled with a solution of uranium-235. Atomics International operates the reactor, which is situated in the Santa Susana Mountains northwest of Los Angeles, as part of the Commission's reactor safety programme. The special test demonstrated the inherent ability of the reactor to shut itself down without the use of auxiliary control rods or devices when an abnormal operating condition occurs. The power surge was so brief that the temperature of the fuel solution was raised only slightly, not enough to cause it to boil. Only moderate pressure lasting for one-thousandth of a second was generated within the reactor vessel. The power was prevented from rising further by the sudden expulsion of fuel solution into an overflow chamber which prevented the nuclear chain reaction from continuing. The expulsion of the fuel solution, in turn, was caused by the generation of gas within the fuel, a characteristic of solution reactors under high power operation.

Personal and Business

Appointments

Mr. I. P. Frost has been appointed managing director of Schieldrop and Co., Ltd.

The Nuclear Power Plant Company, Ltd., announces that Mr. R. D. Vaughan has been appointed a director of the company.

Sharples Centrifuges, Ltd., has announced that Dr. Alan J. Hayter has been appointed director in charge of the technical and sales division.

Mr. George Campbell, A.M.I.Mech.E., has been appointed general manager of the chemical and metallurgical division of The Plessey Company, Ltd.

The Pyrene Company, Ltd., announces the retirement of Mr. W. L. Baker, manager of the metal finishing division. Mr. Baker will be succeeded by Mr. H. A. Holden.

Ashmore, Benson, Pease and Co., has announced that Mr. G. B. Taylor has been appointed sales manager of the works division and Mr. R. H. Foster, A.M.I.C.E., works manager.

British Railways has announced the appointment of Mr. A. N. Butland as chief civil engineer of the London Midland Region. Mr. Butland will succeed Mr. J. Taylor Thompson who retires at the end of this year.

Mr. N. S. Billington has been appointed director of the Heating and Ventilating Research Council. He is succeeded as Head of the National College for Heating, Ventilating, Refrigeration and Fan Engineering by Dr. David R. Scott.

Monsanto Chemicals, Ltd., announces that Mr. D. C. M. Salt has been appointed general manager of the chemical division, and Mr. G. Dodd as general manager of the plastics and special products division. Mr. J. V. Head succeeds Mr. Dodd as acting controller of purchases.

The University of London has announced the following appointments to the Imperial College of Science and Technology with effect from October 1. Dr. Dennis Gabor to the Chair of Applied Electron Physics; Dr. John Sutton to the Chair of Geology and Dr. Russell D'Alton Hoyle to the Readership in Mechanical Engineering.

Mr. W. G. Pinder, managing director of Crossley-Premier Engines, Ltd., has joined the board of the parent company, Crossley Brothers, Ltd. Mr. Hugh Beck and Mr. John Ivor Pugh have been appointed directors of Crossley-Premier Engines, Ltd., and Mr. John Shiels has been appointed secretary and chief accountant of the company.

British Transport Commission announces that it has decided to amalgamate the Mechanical and Carriage and Wagon Engineering Departments in the British Railways Central Staff under one officer, with the title, chief mechanical engineer. Mr. J. F. Harrison has been appointed to this post. Mr. A. E. Robson succeeds Mr. Harrison as chief mechanical and electrical engineer in the London Midland Region.

The Ministry of Supply announces the following appointments: Colonel A. Vaughan-Jones, chief superintendent of ranges; Colonel J. H. Parsons, director of artillery (divisional weapons), and Colonel W. P. St. J. Becher, deputy director of trials and development services, fighting vehicles research and development establishment. Brigadier J. A. Fitzpatrick has been appointed director of munitions (administration), and Colonel M. W. H. Head has been appointed director of fighting vehicles co-ordination.

Business Announcements

Jowett Cars, Ltd. announces that its name has been altered to Jowett Engineering, Ltd.

Galitzine and Partners, Ltd., has moved to 57, Duke Street, Grosvenor Square, London, W.1 (telephone, Mayfair 7377).

Jenkins and Potter, consulting engineers, have moved to 12–15, Great Turnstile, Lincoln's Inn Fields, London, W.C.1 (telephone, Holborn 1291).

Philips Electrical, Ltd., states that the erection of a new building to house the headquarters of its south-west region will shortly commence in Bristol.

The British Commonwealth Chamber of Commerce in the U.S.A., Inc., of New York has changed its name to The British-American Chamber of Commerce.

Coode and Partners states that with effect from September 8, its address will be Abbey House, 2–8, Victoria Street, London, S.W.1 (telephone Abbey 1889, 2794 and 2795).

A.P.V. Company, Ltd. announces that its Chemical Engineering Division has moved from Wandsworth to the company's head offices and works at Manor Royal, Crawley, Sussex.

Alfred Herbert, Ltd. has been appointed sole selling agent in the United Kingdom and Eire for the planing machines and equipment manufactured by Planers (Huddersfield), Ltd.

The Electric Construction Company, Ltd. has established a new Yorkshire area office at Bushbury House, 4, Laurel Mount, St. Mary's Road, Leeds, 7. The area manager is Mr. D. A. Laverack.

Timber Development Association, Ltd., announces that its information officer, Mr. L. G. Jennings, will be stationed at its stand in the timber section of the Building Centre from September 3 onwards.

W. T. Henley's Telegraph Works Company, Ltd., and Johnson and Phillips, Ltd., have announced that the talks which have been taking place with a view to a possible merger of their businesses have now been discontinued.

The Bowater Organisation announces that its Public Relations Department has moved to Bowater House, Knightsbridge, London, S.W.1 (telephone Knightsbridge 7070). The other departments of the organisation will move to the above address by September 15.

Elgar Machine Tool Company, Ltd., 172–178, Victoria Road, Acton, London, W.3, states that it has been appointed exclusive distributor in the United Kingdom for the vertical and horizontal bandsawing and filing machines manufactured by August Mössner K.G., Schwabisch, Germany.

The Institute of Materials Handling announces that its headquarters office has moved from 20–21, Took's Court to 69, Cannon Street, London, E.C.4 (telephone City 4444). Mr. M. W. Paynter, who has served as secretary of the institute since its inception has handed over to Mr. H. M. C. Harwood, due to the pressure of his other commitments.

F. Perkins, Ltd., states that its resident representative in Central America and the Caribbean, Mr. P. W. Percy, will in future be based in the United States instead of Jamaica, and his duties will then also include representing F. Perkins (Canada), Ltd., in the southern states of the U.S.A. Mr. Percy's first assignment on his return from Britain, where he has been on leave, will be a two months' visit with Mr. A. E. Whitwell, North American zone manager of F. Perkins, Ltd., to Toronto, the United States and Central America.

Contracts

The British Transport Commission has just placed orders for a further eighty-three main line diesel locomotives. Of sixty-three 2000 h.p. locomotives for main line passenger service to this order, thirty-three of diesel-hydraulic design will be supplied by the North British Locomotive Company, Ltd., and thirty of diesel-electric design by the English Electric Company, Ltd. The remaining twenty locomotives of 1100 h.p. are for use in general mixed traffic duties and will be of diesel-hydraulic construction by the North British Locomotive Company, Ltd.

Cable Contract for Pirelli-General.—A contract covering the manufacture, supply and installation of some 48,000 yards of cable between Carrington and Moss Nook has been awarded to Pirelli-General Cable Works, Ltd., an associate of The General Electric Company, Ltd., by the Central Electricity Generating Board, North West Merseyside and North Wales Region. This order comprises 132kV three-core and single-core oil-filled, 33kV oil-filled, and 11kV, solid type cables, together with auxiliary cables, pilot cables and accessories. The completion of all cable installation work is scheduled for September 30, 1959. The consulting engineers for the contract are Kennedy and Donkin, London, S.W.1.

The British General Electric Company of Central Africa (Pvt.), Ltd., Salisbury, Rhodesia, has received an order from the Federation of Rhodesia and Nyasaland Federal Power Board for the supply, delivery and erection by Pirelli-General Cable Works, Ltd., of about 90,000 yards of 88kV oil-filled, 33kV oil-filled and solid type cables, 11kV cables, auxiliary cables and accessories. These cables will form part of the Kariba hydro-electric scheme transmission system on the Zambesi River, and will be installed at substations at Sherwood, Norton, Bulawayo, Salisbury, Kitwe and Lusaka. For each of the 88kV circuits, Pirelli-General will supply one trefoil, single-core, 0·75 square inch, 88kV oil-filled cable; and for each 33kV circuit, two trefoils of single-core, 1 square inch, 33kV oil-filled cable. The consulting engineers for the project are Merz and McLellan, Newcastle upon Tyne.

The English Electric Company, Ltd., has been awarded a contract for eight 1840 h.p. diesel-electric locomotives for East African Railways and Harbours. Each locomotive will be powered by an English Electric twelve-cylinder, charge-cooled, SVT diesel engine, will have a 1 Co-Co 1 wheel arrangement and a maximum service speed of 45 m.p.h. The units will be capable of one-man operation and will weigh approximately 100 tons in working order, with a maximum axle load of 13·5 tons. The locomotives, which are designed for metre gauge, will have a continuous tractive effort loading of 44,500 lb, and will be used on the main line services between the Port of Mombassa, Nairobi and Kampala on the shores of Lake Victoria.

Richard Costain, Ltd., has received an order valued at £870,000 for erecting new buildings for the Department of Chemistry of Nottingham University. The main building will be a three-storey structure in reinforced concrete, the external cladding being generally of metal windows with facing brick panels, Westmorland slate cladding and a tooled face to the exposed concrete columns and beams. The overall size is 290ft by 165ft, with floors and roofs generally spanning 20ft to 25ft, although parts of the building include spans of 40ft to 51ft. An inner courtyard will contain a link block and single-storey lecture theatres with basement. The first portion of the chemistry building will be finished in June, 1960, and the whole contract is scheduled for completion later in that year. The architects are Basil Spence and Partners; structural consultants, Ove Arup and Partners; services consultants, A. F. Myers and Partners; quantity surveyors, Gleeds.

Miscellanea

Correction.—In our issue of July 25, page 152, we referred to the Photo-Chronograph made by Julius Peters, Berlin NW 21, Stromstrasse 39. In our article we erroneously stated the maximum film speed to be 100m per second, whereas this figure should have read 200m per second.

"Diagrid" Construction.—In an article entitled "'Diagrid' Floor for U.S. Embassy," on page 307 of The Engineer, dated August 22, 1958, we used the word "Diagrid" in error. We have been asked to state that the Trussed Concrete Steel Company, Ltd., claims to be the proprietor of the trade mark "Diagrid" and that the references to "Diagrid" in the title and the text of the article are incorrect.

Flow Induced by Jets.—The July, 1958, issue of the *Journal of the Aero/Space Sciences* includes a comment by Sir Geoffrey Taylor on the flow induced by jets. In connection with project F.I.D.O., for fog dispersal by jets directed upward, Sir Geoffrey, during the last war, investigated theoretically the entrainment of air by forced and thermal jets, located on a plane or in space, emitted along a line or at a point. The streamlines for the induced flow are given for seven of these cases.

Richborough Power Station.—The Central Electricity Generating Board has received the consent of the Minister of Power to the establishment of a new power station at Richborough, Kent. The total capacity of the station will be 360MW and the plant will consist of three 120MW turbo-generator sets, together with three reheat boilers, each with an evaporative capacity of 860,000 lb of steam per hour. Steam conditions will be 1500 lb per square inch at 1000 deg. Fah., with reheat to the same temperature. The first generating set is scheduled for commissioning in 1962.

A Low-Frequency A.C. Voltmeter.—For the operation of nuclear reactor control rods use is made of very low-speed motors on a three-phase a.c. supply, the frequency of which varies from zero to 2 c/s. When taking voltage measurements at these low frequencies, the instantaneous value of voltage varies so slowly that the pointer of an ordinary instrument has time to follow it, instead of indicating a steady r.m.s. value. A special type of voltmeter developed by Crompton Parkinson, Ltd., however, is basically a d.c. moving coil voltmeter operated from a phase-splitting network with full-wave rectification. This network produces twelve impulses per cycle across the instrument movement, thus reducing the magnitude of the applied ripple voltage and simultaneously increasing its frequency. As a result, the instrument may be used to indicate the r.m.s. value of an applied three-phase voltage at any frequency from 0 to 2500. Tests have shown that the pointer deviation either side of the mean indication amounts to no more than 0·3 per cent at 2 c/s, 0·7 per cent at 1 c/s, and 5 per cent at 0·04 c/s. Both switchboard and portable forms of the instrument are available.

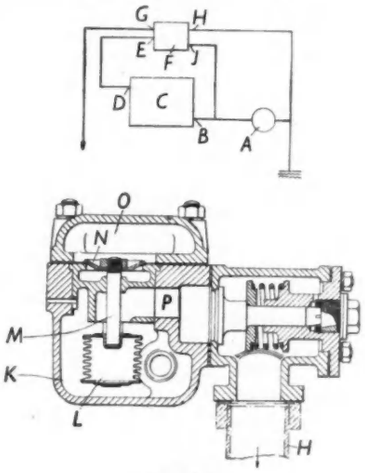
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

INTERNAL COMBUSTION ENGINES

798,967. September 30, 1955.—LIQUID-COOLING SYSTEMS FOR ENGINES, Ruston and Hornsby, L'd., Sheaf Iron Works, Waterside South, in the City and County of Lincoln. (*Inventor: Frederick Leversedge.*)

The invention relates to systems for cooling internal combustion engines by the passage of a liquid, such as water, through a cooling jacket and the drawing shows the invention as applied to a

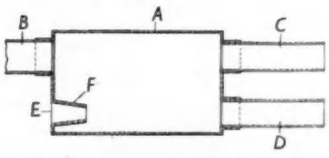


No. 798,967

marine engine. A pump *A* draws up sea water and delivers it to an inlet port *B* into the water jacket of the engine *C* through which the water flows to an outlet port *D* and then to an inlet port *E* to the control unit *F*. Through the control unit *F* the water passes either to an outlet port *G* discharging overboard, or to an outlet port *H* returning to the suction side of the pump *A*. The pump has its outlet side also connected over a by-pass to an inlet port *J* to the control unit. Referring to this unit, the normal stream of water from the engine arriving at the port *E* passes into a thermostat chamber *K* in which is arranged a known type of thermostatic bellows *L* controlling through a spindle *M* the setting of a thermostat valve *N*. When the valve *N* is open by reason of the expansion under the heat of the bellows *L* the waste water flows into the outlet chamber *O*. On the other hand when the engine has not reached operating temperature, the valve *O* is closed, and then the water flow is by-passed through a passage *P* to outlet *H* and back to the suction side of the pump *A*. The system is not self-priming.—*July* 30, 1958.

798,774. September 8, 1955.—EXHAUST SYSTEMS, Vernon Hilton Farthing, 329, Tower Building, Water Street, Liverpool, 3.

According to the invention there is provided an accessory for incorporation in an exhaust system of an internal combustion engine. The accessory shown



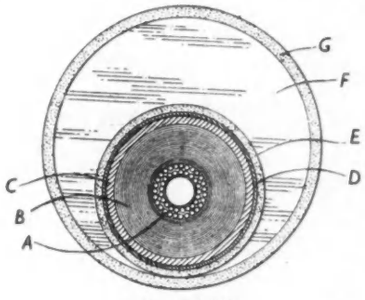
No. 798,774

on the drawing comprises a casing *A*, one end of which has a short length of pipe *B* by which it can be connected to the exhaust end of the somewhat shortened silencer outlet pipe of a motor vehicle. At its opposite end the casing *A* has twin outlet pipes *C* and *D*. The outlet pipe *C* is in axial alignment with the inlet pipe *B*. At the inlet end of the casing is an opening *E* which is fitted with a convergent nozzle or jet *F* and serves for the introduction of atmospheric air into the casing, the motion of the vehicle promoting this flow of air. It will be noted that the jet *F* is in axial alignment with the outlet pipe *D*. The corrector unit forms an auxiliary to the normal exhaust system of the motor vehicle and with it the air flow, due to the motion of the vehicle and controlled by the nozzle structure, prevents or reduces the partial vacuum effect. The inertia of the air in the casing and constant cold air flow tends substantially to prevent the back flow surge effect from the outlet end of the exhaust pipe back to the exhaust port itself. Given appropriate physical dimensions and speed of vehicle or air flow, the unit can be extended so as to act as an extractor for the exhaust gases which of course further extends its function and promotes its efficiency.—*July* 30, 1958.

ELECTRICAL ENGINEERING

798,996. February 6, 1957.—UNDERGROUND HIGH-TENSION ELECTRIC CABLE SYSTEMS, Pirelli Societa per Azioni, Viale Abruzzi 94, Milan, Italy.

The invention relates to underground high-tension electric cable systems in which the cables are laid in underground ducts. The cable comprises a pipeline of synthetic plastics tubes laid underground; one or more cables are enclosed in the pipeline, and a good heat-conducting liquid, which is independent of the electric operation of the cable, fills the free space within the line. The liquid in the plastics pipe may be a mineral or vegetable oil or water, to which an anti-freezing agent has been added if necessary, the purpose of liquid being to reduce to a minimum the thermal resistance of the interspace between the cable or cables and the plastic pipe. Referring to the drawing, *A* is the hollow

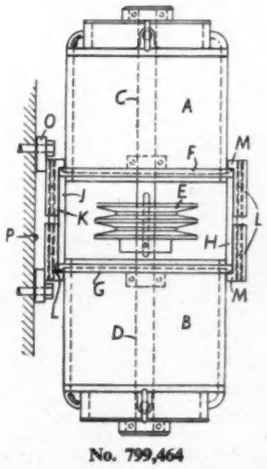


No. 798,996

stranded conductor of a cable, *B* the insulation of impregnated paper, *C* the impermeable sheath, for example, of lead, *D* the transversal reinforcement of the sheath *C*, the sole function of which is to reinforce the sheath transversely so as to withstand the internal pressure of the cable, and which consists of a metal strip, for example made of brass, wound in close turns on the sheath itself with the interposition of a thin layer of fabric, generally bitumenised, which acts as a pad. This reinforcement may be single, or double, but it could be dispensed with if not required. Finally, *E* indicates the sheath of low-friction plastics material, *F*, the heat-conducting liquid, and *G* the tube, made for example of rigid polyvinyl chloride. Various arrangements for underground cables are shown in the Specification.—*July* 30, 1958.

799,464. October 12, 1956.—ELECTROMOTORS, Gerald Harold Denford, Denford Small Tools (Brighouse), Ltd., Victoria Works, Birds Royd, Brighouse, Yorkshire.

The invention relates to improvements in electromotors intended to serve as power units in connection with machine tools and for any other suitable purpose,

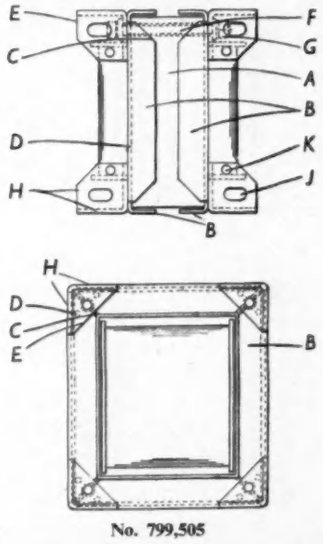


No. 799,464

an object being to provide a unit which is capable of two or more different power outputs having a central or balanced power take-off point and which may be easily and quickly attached to a machine and adjusted through 360 deg. From the drawing it will be seen that *A* and *B* are the casings of two motors with their axially aligned shafts *C* and *D* coupled together by a grooved pulley *E*. Near the end of each casing there is secured to each motor a ring *F* and *G* spaced by two or more distance pieces *H* and *J*. The motors and distance pieces are adapted to be rigidly secured together by two pairs of clamps *K* and *L*, whose shoulders *M* engage behind the rings *F* and *G* and are drawn together by right and left-hand threaded bars. One pair of clamps *K* has bored bosses or flanges *O*, whereby the unit may be attached to a machine frame *P* by bolts. By slackening the bolts of the clamps the motors may be swung through 360 deg. about their axis and locked in position.—*August* 6, 1958.

799,505. March 25, 1955.—A TRANSFORMER CORE CLAMPING DEVICE, The Mullard Radio Valve Company, Ltd., Spencer House, South Place, Finsbury, London, E.C.2. (*Inventor: Guy Birkbeck.*)

The invention relates to transformer core clamping devices. The laminations of a transformer must be tightly clamped to ensure reliability in service and high efficiency but it is also desirable that the clamping device employed should be easily assembled, and accordingly objects of the present invention are to provide an improved clamping device which seeks to satisfy these requirements and which has parts which are suitable for use with various sized cores. As will be seen from the drawing the core *A* of the transformer has eight angle-section members *B* the limbs of which are fitted about the edges of the outermost lamination of each face of the core *A*. The ends of the limbs of each member *B* are cut at an angle of 45 deg. to produce an edge *C*. The edges of two adjacent limbs are arranged to abut each other on the face of the outermost lamination and a substantially circular aperture is formed when the edges *C* are placed together, thus permitting the passage of a bolt. A recess *D* is formed adjacent the end of each limb and this co-operates with a corresponding projection on one face of a corner member *E*. The projection is formed by part-piercing, whereas the recess has the form of a punched aperture. Thus at each corner of the clamp two projections on one face



No. 799,505

of the corner member each co-operate with a recess in a limb of a member *B* and when a nut and bolt assembly *F* and *G* (shown in broken lines in the upper view) is tightened, the angle-sectioned members cannot be displaced. Similar corner members *E* are provided at each corner of the clamp and when the corresponding nuts and bolts are tightened a substantially rigid structure is formed. The construction prevents both lateral movement of the angle-sectioned members and rotational movement of the corner members when the bolts are tightened.

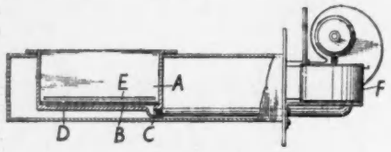
To facilitate fixing of the transformer to a chassis or other mounting structure in any one of a variety of positions, each corner member is provided with two flanges *H* arranged at right angles; and at right angles to the face of the member abutting the ends of the angle-section members *E* are formed with a slot *J* and a circular aperture *K*. Tag boards may be mounted in a number of positions by means of bolts passing through a spacer and through the aperture *K*. The slots *J* enable the transformer to be mounted on a chassis or similar member. It will be

readily appreciated that a transformer clamp such as that described may be readily assembled and demounted and furthermore the parts are interchangeable for a given size of core and that the same size corner members may be utilised in conjunction with a range of core sizes.—*August* 13, 1958.

BURNERS AND SPRAYERS

799,931. August 12, 1953.—OIL BURNERS, Plant Heating Units, Ltd., 52, Wellington Road North, Stockport, Cheshire. (*Inventors : Gerald Lahan and Arthur Roy Simpkin.*)

The invention relates to " pot burners " employed for burning paraffin and like oils, under forced draught for the heating of boilers and furnaces. As will be seen from the drawing a burner assembly comprises

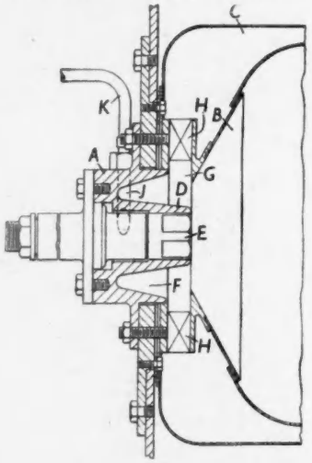


No. 799,931

a hollow rectangular box- or trough-shaped burner *A* approximately 9in in length, 4½in in width, and 3½in in depth. On the base of the burner, there is an integrally-formed reservoir *B* which is separated from the inside of the trough by a base-plate *D*, communication between the reservoir and the trough being made by a series of rows of holes in the base-plate at approximately 1½in centres. Each of the holes is approximately $\frac{3}{16}$in in diameter. Seven rows of holes are provided about ¼in apart and the rows are staggered. A suitable inlet *C* at one end of the reservoir serves to receive a conduit through which oil may be fed to the trough. Longitudinally in each longer side of the burner and at about ½in from the base-plate is a slot *E* through which air may be forced to the burner. The burner *A* is accommodated in a substantial metal casing *K* and an adjustable-delivery blower or fan forces air to the burner through the casing. A metering valve *F* serves to control the flow of paraffin to the reservoir.—*August* 13, 1958.

799,364. March 1, 1956.—PULVERISED FUEL BURNERS, Joseph Lucas (Industries), Ltd., Great King Street, Birmingham, 19. (*Inventors : George Roland Wade and John Marsland.*)

The invention has for its object to provide in a simple form a burner for pulverised solid fuel. Referring to the drawing, a body part *A* is secured to the



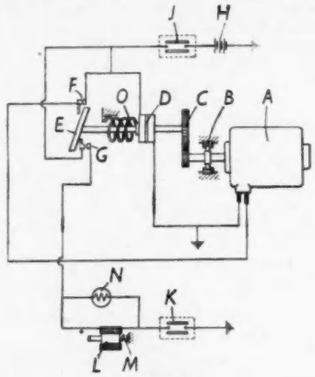
No. 799,364

entrance end of a combustion chamber *B*, surrounded by an air jacket *C* which receives air from a blower. On the central axis of the body is a hollow boss *D* which carries a liquid fuel spraying nozzle *E* for providing the igniting flame. Around this boss is an annular tapering cavity *F* which is open at one end. Adjacent to its open end this cavity is surrounded by an annular air duct *G* formed between a pair of flat surfaces which contain between them a number of guide vanes *H*. This duct is so positioned that it can receive air at its outer periphery from the air jacket, the air being discharged into the cavity *F* as a swirling stream. Adjacent to the closed end of the cavity the body has formed in it a passage *J* tangential to the outer periphery of the cavity *F*, and at the outer end of this passage is a pipe *K* which conveys the pulverised fuel. When the burner is in action the stream of pulverised fuel is fed into the air stream, where it becomes intimately mixed with the air and then passes to the combustion chamber. Ignition of the dust-air mixture is initiated by ignition of the oil spray, ignited by any convenient electric torch or other means. Thereafter, ignition is maintained by the flame of the dust-air mixture in the combustion chamber.—*August* 6, 1958.

AIRSCREWS

799,899. February 20, 1956.—VARIABLE PITCH PROPELLERS FOR AIRCRAFT, The Rolls-Royce, Ltd., Nightingale Road, Derby. (*Inventor : Arthur Roy Barnard.*)

The invention relates to improvements in the automatic control of the pitch of airscrews. According to it the airscrew pitch-adjusting means includes a stop preventing the reduction of the airscrew pitch beyond a predetermined limit, automatic means operated when a load is placed on the aircraft undercarriage for removing the stop to permit the pitch to be reduced beyond the predetermined limit, and a delayed action device associated with such automatic means which delays removal of the stop until the load on the undercarriage has been maintained for a predetermined period of time. The drawing shows *A*, a constant speed electric motor which drives through a free-wheel device *B*, a reduction gear *C* and a magnetic clutch *D*, and a rotary cam *E*. The free-wheel is so arranged that the motor cannot be rotated in the reverse direction. Associated with the rotary cam are a pair of contacts *F* and *G*. In the



No. 799,899

position shown in the drawing the contacts *F* are closed and the contacts *G* open. When the cam is rotated through 180 deg. contacts *F* are opened and contacts *G* closed. It is so arranged that the contacts *F* open a short time after contacts *G* have closed. A source of electrical energy *H* is isolated from the aforesaid parts by a switch *J* which is made only when either the nose wheel or the port wheel have moved upward on the load of the aircraft coming on to them on landing. A similar switch *K*, which is closed only when the nose wheel or starboard wheel are loaded, is arranged in a circuit which includes the contacts *G* in series and a solenoid *L* by which the fine pitch stop is withdrawn against the reaction of a spring *M*. A warning light *N*, which lights to show the pilot that the stop has been withdrawn, when this circuit has been made, is connected in parallel with the solenoid *L*. When the switch *J* has been operated the circuit through the magnetic clutch *D* is closed and the circuit through the electric motor is also closed through the contacts *F*. The motor will accordingly drive the cam *E* to close contacts *G* and open contacts *F*. Loading having come on to the wheels, switch *K* is operated and the circuit is completed through the solenoid *L* and the warning light *N* and the stop is withdrawn. A resetting coil spring *O* is provided which is wound up by the rotation of the cam *E*. As long as the switch *J* is closed and the magnetic clutch is engaged the free-wheel device *B* will prevent the spring returning the cam to its starting position, but when the switch *J* is again opened by the load coming off the undercarriage the magnetic clutch isolates the gears *C*, the free-wheel *B*, and the motor *A*, from the cam and the spring *O* will return the cam to the starting position shown in the drawing. A delay of about three seconds may be sufficient between the moment when the load comes on to the wheels, and the moment when the stop is removed and the motor is arranged to produce the amount of delay. Should the load be removed from the wheels during this period, as when the aircraft bounces or proceeds to start to take off again, then the electrical circuit to the motor and the magnetic clutch is broken and the stop removal prevented. In this case the delayed-action device returns to its initial position of setting, so that on the next attempt to land the same period of delay will again be experienced. With such an arrangement separate manual controls will be provided for the throttle valve and the constant speed governor unit of the pitch-adjusting mechanism so that these are operable independently and not as is sometimes present practice by a single control lever.—*August* 13, 1958.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

WELDING SYMBOLS WALL CHART

No. 499C : 1958. Price 6s. mounted and 3s. unmounted. This chart boldly presents a collection of British Standard welding symbols reproduced from No. 499. The symbols denote the type, size and position of welds in welded joints, and are accompanied by illustrations showing examples of their use.

COLD ROLLED STEEL SECTIONS

No. 2994 : 1958. Price 8s. 6d. The dimensions, weights and geometric properties of a basic range of cold rolled steel sections are specified in this new British Standard (30 pages, illustrated). The sections are of the type formed by cold rolling from steel strips, and the sizes specified are those in common production. The eleven tables deal with equal and unequal angles, inwardly-lipped and outwardly-lipped channels—and with tees and compound sections made up from them. They are preceded by a number of general requirements and by a clause which deals fully with the subject of tolerances.

GLOSSARY OF TERMS USED IN VIBRATION AND SHOCK TESTING

No. 3015 : 1958. Price 5s. This glossary contains seventy-two definitions of interest to those concerned with the study and testing of the behaviour of equipment when subjected to shock and vibration. A few of the definitions (e.g. " isolator," " snubber ") have a specialised meaning in vibration and shock testing but most of them have a wide general use ; the glossary does, however, clarify their meanings for use within the field it covers. The eighteen-page publication concludes with mathematical Appendices on " Line spectra," " Continuous spectra " and " Spectra of experimentally determined quantities."

FILAMENT LAMPS

No. 941 : 1958. Price 12s. 6d. Two important revisions are included in this new edition of B.S. 941, which supersedes the 1956 edition. For the first time, the standard refers to lamps of the pre-focus type, using the P.22 British pre-focus cap. Detailed requirements are specified for the positioning of the filaments, and for verifying the position by projecting magnified images of the filaments on to a test screen upon which targets with the permitted tolerances are drawn. Also for the first time, the inspection and rating tests are based on a system of double sampling. Although well known to statisticians, this system has not previously been used in test specifications for electric lamps. The effect of the procedure is to reduce considerably the amount of testing, without reducing its effectiveness as a protection to the user. The standard includes thirteen schedules of ratings, dimensions and requirements for initial readings and life test for all lamps. The schedules also allocate reference numbers to all those types of lamp which are best known and widely used in industry.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF PUBLIC LIGHTING ENGINEERS

Tues., to Fri., Sept. 16 *to* 19.—Annual conference, Harrogate. " Lighting for Safety and Amenity."

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Today, Sept. 5.—BRISTOL AND WEST OF ENGLAND BRANCH : Grand Hotel, Bristol, " Joint Boiler-House District Heating," F. C. Cummins ; Chairman's Address, 8 p.m. ★LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, Chairman's Address, J. S. Buck, 7.30 p.m.

Mon., Sept. 8.—BOLTON BRANCH : Railway Hotel, Trinity Street, Bolton, " Display Lighting," A. White, 7.45 p.m. ★CENTRAL LONDON BRANCH : White Hall Hotel, Bloomsbury Square, London, W.C.1, " Artificial Satellites and the International Geophysical Year," K. Ward, 7.15 p.m. ★NORTH WEST LONDON BRANCH : Century Hotel, Forty Avenue, Wembley Park, Middlesex, Open Meeting, 8.15 p.m.

Tues., Sept. 9.—PORTSMOUTH AND DISTRICT BRANCH : Ministry of Labour and National Service, Lake Road, Portsmouth, " Trinity House (Signalling and Lighting)," J. W. Nichols, 7.30 p.m. ★READING AND DISTRICTS BRANCH : Electricity Board Demonstration Room, Market Square, Reading, Inaugural Branch Meeting, 7.15 p.m. ★SOUTH WALES BRANCH ; Angel Hotel, Cardiff, " The Diesel Engine as a Power and Heating Unit," P. Makin, 7.30 p.m. ★YORK BRANCH : " Georgian House," Blossom Street, York, " Refrigeration," A. J. Simpson, 7.30 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Sept. 9.—EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, Members' Evening, 7 p.m. ★MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, Chairman's " At Home," 7.15 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Sat., Sept. 6.—WOLVERHAMPTON GRADUATE SECTION : Morning visit to Fisher and Ludlow, Ltd., Birmingham.